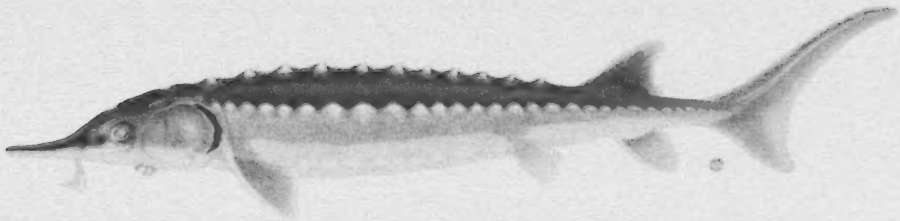
COSEWIC
Assessment and Status Report

on the

Atlantic Sturgeon
Acipenser oxyrinchus

St. Lawrence populations
Maritimes populations

in Canada



THREATENED
2011

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

COSEWIC. 2011. COSEWIC assessment and status report on the Atlantic Sturgeon *Acipenser oxyrinchus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xiii + 49 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

Production note:
COSEWIC acknowledges Robert Campbell for writing the provisional status report on the Atlantic Sturgeon, *Acipenser oxyrinchus*. The contractor's involvement with the writing of the status report ended with the acceptance of the provisional report. Any modifications to the status report during the subsequent preparation of the 6-month interim and 2-month interim status report were overseen by Dr. Eric Taylor, COSEWIC Freshwater Fishes Specialist Subcommittee Co-Chair.

For additional copies contact:

COSEWIC Secretariat
c/o Canadian Wildlife Service
Environment Canada
Ottawa, ON
K1A 0H3

Tel.: 819-953-3215
Fax: 819-994-3684
E-mail: COSEWIC/COSEPAC@ec.gc.ca
http://www.cosewic.gc.ca

Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur l'esturgeon noir (*Acipenser oxyrinchus*) au Canada.

Cover illustration/photo:
Atlantic Sturgeon — from Cornell University Department of Natural Resources by permission.

©Her Majesty the Queen in Right of Canada, 2011.
Catalogue No. CW69-14/636-2011E-PDF
ISBN 978-1-100-18706-8

Recycled paper

COSEWIC
Assessment Summary

Assessment Summary – May 2011

Common name
Atlantic Sturgeon - St. Lawrence populations

Scientific name
Acipenser oxyrinchus

Status
Threatened

Reason for designation
This large-bodied, slow-growing, and late-maturing fish consists of a small breeding population spawning within a relatively small area. The species is exploited in a regulated commercial fishery, but limited monitoring of the effects of this fishery make the viability of this population highly uncertain.

Occurrence
Quebec, Atlantic Ocean

Status history
Designated Threatened in May 2011.

Assessment Summary – May 2011

Common name
Atlantic Sturgeon - Maritimes populations

Scientific name
Acipenser oxyrinchus

Status
Threatened

Reason for designation
This large-bodied, slow-growing and late-maturing fish spawns only within the lower Saint John River area. The species has a relatively small breeding population and is subject to regulated commercial and recreational fisheries. These fisheries, however, receive limited monitoring in terms of their effects on this species making its viability highly uncertain.

Occurrence
New Brunswick, Nova Scotia, Atlantic Ocean

Status history
Designated Threatened in May 2011.

COSEWIC
Executive Summary

Atlantic Sturgeon
Acipenser oxyrinchus

St. Lawrence populations
Maritimes populations

Species information

The Atlantic Sturgeon is a member of one of the oldest groups of living fishes. All sturgeon are characterized by having an internal skeleton composed of cartilage, a bottom-oriented mouth bordered with fleshy barbels, and a set of bony projections or "scutes" occurring in rows along the body. The Atlantic Sturgeon is recognized by a particular arrangement of the scutes and an elongate body with a slightly upturned snout. The Atlantic Sturgeon is an anadromous species that resides and matures in the sea, but spawns in freshwater, which also serves as juvenile rearing habitat. Mature female Atlantic Sturgeon attain an average total length of 2 - 3 m and weigh between 100 - 200 kg; mature males are smaller at 1.4 - 2.1 m total length and weigh 50 - 100 kg. Genetic information suggests both regional and population-level structure and the existence of two designatable units (DUs): St. Lawrence River and Maritimes DUs.

Distribution

Atlantic Sturgeon occur in rivers, estuaries, nearshore marine environments and the shelf regions to at least 50 m depths along the Atlantic coast of North America. They range as far north as Ungava Bay, Labrador, into the Gulf of St. Lawrence, southward on the Atlantic coast to Florida and along the coast of the Gulf of Mexico.

Habitat

The important habitat for Atlantic Sturgeon is a river with access to the sea, preferably with deep channels; an estuary with relatively warm, partially saline water and a coastal shelf region. Atlantic Sturgeon spawn in freshwater over rocky-gravel substrates at a depth of 1 - 3 m in areas with a strong current, and also under waterfalls, and in deep pools. The probable limiting factor for each river population is the size of the juvenile nursery region in the brackish estuarine waters. Habitat loss and/or degradation resulting from human activity had severely impacted riverine habitats in the 20th century, although recovery efforts have led to improved conditions in many areas.

Biology

Age of maturity for Atlantic Sturgeon varies according to sex and latitude; males mature earlier and at a smaller size than females. In Canadian waters, males first mature at 16 - 24 years of age at a size of about 150 cm fork length (FL) and females at an age of 27 - 28 years and a size of 180-200 cm FL. The generation time is estimated as about 40 years. Not all mature adults spawn every year; females probably spawn once in every 3 to 5 years and males once in 5 years. Spawning in Canada occurs in June and July at temperatures of 16 - 20°C, the eggs hatch in 3 - 7 days and the juveniles grow rapidly, reaching 10 cm in 2 - 4 months, and 20 - 35 cm by the end of their first year of growth. They migrate to sea at a size of 80 - 120 cm. These large, slow growing, late-maturing fish may live for several decades. Atlantic Sturgeon can produce a great number of eggs; large females may contain well over 1,000,000 eggs. Atlantic Sturgeon feed on benthic invertebrates in freshwater and in brackish water. Larger juveniles and adults may also consume small fish.

Population sizes and trends

Breeding populations are known from the St. Lawrence and Saint John rivers, and possibly in other rivers tributary to the Bay of Fundy and Gulf of St. Lawrence. There may be between 500 and 1,000 adults in the St. Lawrence River DU and a likely minimum of 1,000 - 2,000 in the Maritimes DU, but reliable estimates do not exist.

Limiting factors and threats

Threats to the Atlantic Sturgeon include lack of quantitative data on population responses to exploitation, changes to riverine habitat from hydroelectric facility operations, alteration to benthic habitats from dredging work and, potentially, pollution in rivers and from offshore oil and gas developments. Commercial fishing and pollution may have been the most significant factors that caused suspected declines in Atlantic Sturgeon populations in the past.

Special significance

The Atlantic Sturgeon is significant both biologically and commercially. Biologically, it has been of interest to science with its ancestry leading back at least 200 million years. Commercially, it is valued to some extent for its flesh, which is usually smoked and brings a high price per kilogram. Archaeological evidence and oral history dating back some 2,400 years suggests that Atlantic Sturgeon were important to Aboriginal peoples for food and other uses prior to the 20th century.

Existing protection

Internationally, Atlantic Sturgeon are listed under Appendix II to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and are listed globally as Vulnerable (G3) by NatureServe and Near Threatened by the IUCN. In Canada, the overall authority for sturgeon management rests with the Department of Fisheries and Oceans under terms of the *Fisheries Act.* By agreement with the federal government, the responsibility in Quebec rests with the provincial government.

TECHNICAL SUMMARY – St. Lawrence Populations

Acipenser oyxrinchus
Atlantic Sturgeon — Esturgeon noir
St. Lawrence Populations — Populations du Saint-Laurent
Range of occurrence in Canada: Quebec and Atlantic Ocean - St. Lawrence River from approximately Trois-Rivières downstream to and including the estuary and adjacent waters of the Atlantic Ocean.

Demographic Information

Generation time (average age of parents in the population)	~40 yr
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Unknown
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]. Probably stable	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last 10 years (or three generations). Probably stable	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next 10 years (or three generations) Probably stable	Unknown
[Observed, estimated, inferred or suspected] percent [reduction or increase] in total number of mature individuals over any 10 year period (or three generations) over a time period including both the past and the future. Probably stable	Unknown
Are the causes of the decline clearly reversible and understood and ceased? Evidence for decline from historical levels is equivocal and based on fishery landings with no adjustment for effort fluctuations.	NA
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated Extent of Occurrence (EO) [minimum convex polygon, excluding terrestrial area). Marine area overlap with Maritimes DU is 27,564 km²	252,574 km²
Index of Area of Occupancy (IAO) 2 X 2 km overlaid grid (based on spawning areas)	104 km²
Is the total population severely fragmented?	No
Number of "locations*" (based on potential overexploitation in the fishery)	one
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	No
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy?	Probably not
Is there an [observed, inferred, or projected] continuing decline in number of populations?	No
Is there an [observed, inferred, or projected] continuing decline in number of locations?	No
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat?	Probably not
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of mature individuals (in each population)

Population	N Mature Individuals
Middle St. Lawrence River	~500-1,000
Total	500-1,000

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years]. Bayesian Belief Network analysis resulted in 45% EN, 50% TH, 3% SC, 1% NAR	Not Conducted (necessary data not available)

Threats (actual or imminent, to populations or habitats)

Immediate

Lack of quantitative fisheries data on sustainability (potential for overexploitation)

Potential

Pollution, poor water quality, habitat modification from dredging, oil and gas developments in Gulf of St. Lawrence.

Rescue Effect (immigration from outside Canada)

Remnant populations remain in nearby rivers in Maine, extirpated from some rivers in New Hampshire, Massachusetts, Rhode Island and Connecticut. Formerly large populations in the Hudson and Delaware Rivers now less than 20% of historical levels with no signs of recovery (Table 1, *see also* **Current Status** below).

Is immigration known or possible?	Unlikely
Would immigrants be adapted to survive in Canada?	Probably
Is there sufficient habitat for immigrants in Canada?	Probably
Is rescue from outside populations likely? Possible, but unlikely given low abundance and poor status of outside populations	No

Current Status

COSEWIC: Threatened (May 2011)
NatureServe: Regional QC: S3S4
Wild Species 2005 (Canadian Endangered Species Council 2006)
Regional – QC Conservation Data Centre S3S4

Status and Reasons for Designation

Status:	**Alpha-numeric code:**
Threatened	D2

Reasons for Designation:

This large-bodied, slow-growing, and late-maturing fish consists of a small breeding population spawning within a relatively small area. The species is exploited in a regulated commercial fishery, but limited monitoring of the effects of this fishery make the viability of this population highly uncertain.

Applicability of Criteria

Criterion A: Not applicable. Insufficient data to estimate declines or their magnitude.
Criterion B: Meets B2 (EN) as IAO < 500 km^2, meets sub-criterion **a** (1 location), but no other sub-criteria.
Criterion C: Meets EN for C as total number of mature individuals thought to be < 2,500, but data are insufficient to estimate declines.
Criterion D: Meets TH, D2 (one location)
Criterion E: Not conducted (necessary data not available)

TECHNICAL SUMMARY – Maritimes population

Acipenser oxyrinchus
Atlantic Sturgeon — Esturgeon noir
Maritimes populations — Populations des Maritimes
Range of occurrence in Canada: NB, NS (accidental in PE and NL) including adjacent waters of the Atlantic Ocean.

Demographic Information

Generation time (average age of parents in the population)	~40 yr
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals? Probably stable	Unknown
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]. Probably stable	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last 10 years (or three generations). Suspected to be at least 30% given large declines in catches, but there has been no accounting of effort changes.	Unknown, probably at least 30%
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next 10 years (or three generations). Probably stable	Unknown
[Observed, estimated, inferred or suspected] percent [reduction or increase] in total number of mature individuals over any 10 year period (or three generations) over a time period including both the past and the future. Probably stable	Unknown
Are the causes of the decline clearly reversible and understood and ceased? Evidence for decline is equivocal and based on fishery landings with no adjustment for effort fluctuations.	NA
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated Extent of Occurrence (EO) (minimum convex polygon excluding terrestrial area) area of overlap with GL-St. Lawrence DU = 27,562 km^2	330,539 km^2
Index of Area of Occupancy (IAO) 2 X 2 km overlaid grid (based on all areas used in Saint John River as spawning areas are unknown)	612 km^2
Is the total population severely fragmented?	No
Number of "locations*" (based on potential for overexploitation in the fishery) Reports of fish in Avon and Annapolis River, but these are suspected to be vagrants	Probably one
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	No
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy?	Probably not
Is there an [observed, inferred, or projected] continuing decline in number of populations?	No
Is there an [observed, inferred, or projected] continuing decline in number of locations?	No
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat?	Probably not

Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of mature individuals (in each population)

Population	N Mature Individuals
Bay of Fundy area: Saint John River Rough estimate of likely minimum	1,000-3,000
Total	≥ 2,000

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years]. Bayesian Belief Network resulted in 25% EN, 67% TH, 4% SC, 4% NAR	Not Conducted (necessary data not available)

Threats (actual or imminent, to populations or habitats)

Immediate

Lack of quantitative fisheries data on sustainability (potential for overexploitation)

Potential

Pollution, poor water quality, habitat modification from dam operations, oil and gas developments in Gulf of St. Lawrence

Rescue Effect (immigration from outside Canada)

Remnant populations remain in nearby rivers in Maine, extirpated from some rivers in New Hampshire, Massachusetts, Rhode Island and Connecticut. Formerly large populations in the Hudson and Delaware Rivers now less than 20% of historical levels with no signs of recovery (Table 1, *see also* **Current Status** below).

Is immigration known or possible?	Unlikely
Would immigrants be adapted to survive in Canada?	Probably
Is there sufficient habitat for immigrants in Canada?	Probably
Is rescue from outside populations likely? U.S. populations in decline; DU1 has lower estimated population size	No

Current Status

COSEWIC: Threatened (May 2011)
NatureServe: Regional: NB – S3, NL – SNR, NS – S1?
Wild Species 2005 (Canadian Endangered Species Council 2006)
Regional NB – 3, NS 2

Recommended Status and Reasons for Designation

Recommended Status:	Alpha-numeric code:
Threatened	D2

Reasons for Designation:

This large-bodied, slow-growing and late-maturing fish spawns only within the lower Saint John River area. The species has a relatively small breeding population and is subject to regulated commercial and recreational fisheries. These fisheries, however, receive limited monitoring in terms of their effects on this species making its viability highly uncertain.

Applicability of Criteria

Criterion A: Not applicable. Insufficient data to estimate magnitude of decline.
Criterion B: Meets B2 (TH) as IAO < 2,000 km^2, sub-criterion **a** (1 location), but no sub-criteria.
Criterion C: Criteria not met; insufficient data to estimate population size or declines.
Criterion D: Meets TH, D2 (one location)
Criterion E: Not conducted (necessary data not available)

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2011)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment Canada / Environnement Canada
Canadian Wildlife Service / Service canadien de la faune
Canada

The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

COSEWIC Status Report

on the

Atlantic Sturgeon
Acipenser oxyrinchus

St. Lawrence populations
Maritimes populations

in Canada

2011

TABLE OF CONTENTS

WILDLIFE SPECIES INFORMATION 4
Name and classification 4
Morphological description 4
Spatial population structure and variability 6
Designatable units 10
Special significance 11
DISTRIBUTION 12
Global range 12
Canadian range 12
HABITAT 14
Habitat requirements 14
Habitat trends 16
Habitat protection/ownership 17
BIOLOGY 17
General 17
Reproduction 18
Survival 20
Physiology 20
POPULATION SIZES AND TRENDS 23
Search effort 23
Abundance and trends 24
Rescue effect 30
LIMITING FACTORS AND THREATS 31
Exploitation 31
Pollution 33
Habitat loss and/or degradation 34
Bayesian belief network analysis 35
EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS 36
Canada 36
United States 37
International 38
ACKNOWLEDGEMENTS 38
INFORMATION SOURCES 38
BIOGRAPHICAL SUMMARY OF REPORT WRITER 49
COLLECTIONS EXAMINED 49
AUTHORITIES CONSULTED AND PERSONAL COMMUNICATIONS 49

List of Figures

Figure 1. Atlantic Sturgeon, *Acipenser oxyrinchus* (courtesy USFWS). 5

Figure 2. North American distribution of Atlantic Sturgeon. Stars indicate known and potential spawning populations, and squares summer concentration sites in the inner Bay of Fundy (insert) [adapted from Dadswell 2006]. 9

Figure 3. Extents of occurrence for St. Lawrence River and Maritime DUs of Atlantic sturgeon (*Acipenser oxyrinchus*). The narrow rectangular outline and the easternmost dashed line represent fishery zones for various marine fishes. 14
Figure 4. Atlantic Sturgeon aggregation and potential spawning sites areas identified in the St. Lawrence River (adapted from Hatin *et al.* 2002). 15
Figure 5. Commercial landings of Atlantic Sturgeon in the Saint John River, New Brunswick, from 1882 - 2002 (from Dadswell 2006; DFO 2009b). Landing statistics from 2004 - 2009 were not available at the time of writing. 25
Figure 6. Length frequency distributions of the commercial catch of male and female Atlantic Sturgeon in the Saint John River for the years (a) 1998 and 1999, and (b) 2007 and 2008 (from DFO 2009a). 26
Figure 7. Estimated age structure of Atlantic Sturgeon captured in the 2008 commercial harvest on the Saint John River using Von Bertalanffy data from Magnin (1964) for the St. Lawrence River (Linf = 314.7, t0 = -0.7542, K = 0,0315). From DFO (2009a) 27
Figure 8. Estimated age structure of female Atlantic Sturgeon captured in the 2008 commercial harvest on the Saint John River using growth information from the St. Lawrence River population to the north and the Hudson River population to the south (from DFO 2009a). 27
Figure 9. Commercial landings of Atlantic Sturgeon in the St. Lawrence River, 1939 - 2006 (after Dadswell 2006; DFO 2009b) 29

List of Tables

Table 1. Current status of known or postulated populations of Atlantic Sturgeon, *Acipenser oxyrinchus oxyrinchus*. 6
Table 2. Values for extent of occurrence (EO) and index of area of occupancy (IAO) in km^2 for Atlantic sturgeon (*Acipenser oxyrinchus*). All units are in km^2. The values in parenthesis for EO represent the extent of overlap between the two DUs. Index of area of occupancy is for a 2 x 2 km^2 grid with the value for a 1 x 1 km^2 grid in parentheses. 13

WILDLIFE SPECIES INFORMATION

Name and classification

Class:	Actinopterygii
Order:	Acipenseriformes
Family:	Acipenseridae:
Genus:	*Acipenser*
Species:	*oxyrinchus*
Scientific Name:	*Acipenser oxyrinchus* Mitchell 1815 (Nelson *et al.* 2004)
Common Name:	
English:	Atlantic Sturgeon
French:	Esturgeon noir

The Atlantic Sturgeon is one of five species of *Acipenser* in Canada and is represented by two subspecies, *A. o. oxyrinchus*, which ranges along the Atlantic coast from Labrador to Florida and formerly into the Baltic Sea (Ludwig *et al.* 2002), and *A. o. desotor*, which ranges from the Gulf of Mexico coast of Florida to northern South America (Vladykov and Greeley 1963). Differences between the two subspecies include the length of the spleen, pectoral fins and head, as well as the shape of the scutes (Vladykov and Greeley 1963). Genetic data (Ong *et al.* 1996) support the subspecies designation and also reveal population and regional differences along the Atlantic and Gulf coasts (Waldman and Wirgin 1998).

Morphological description

The Atlantic Sturgeon (Figure 1) is an anadromous species that resides and matures in saltwater, but spawns and feeds as juvenile fish in freshwater (Krayushkina 1998). Mature female Atlantic Sturgeon attain an average total length of 2 - 3 m and weigh between 100 - 200 kg, mature males are slightly smaller at 1.4 - 2.1 m total length (TL) and 50 - 100 kg in weight (Smith 1985; Scott and Scott 1988; Collins *et al.* 2000). The largest reported Atlantic Sturgeon was a 4.6 m female, weighting 365 kg that was caught in the Saint John River estuary, New Brunswick in 1924 (Scott and Scott 1988). Large fish are still seen from time to time; between 1973 and 1995, seven individuals of approximately that size were observed in the Saint John River estuary (M. Dadswell, personal observations, 2009). They were not removed from the water for accurate measurements, but they were approximately the same length as a 4 m boat from which they were observed. The largest fish taken in the St. Lawrence River was a 2.7 m (TL) female weighing 160 kg, estimated to be 60 years old (Magnin 1962).

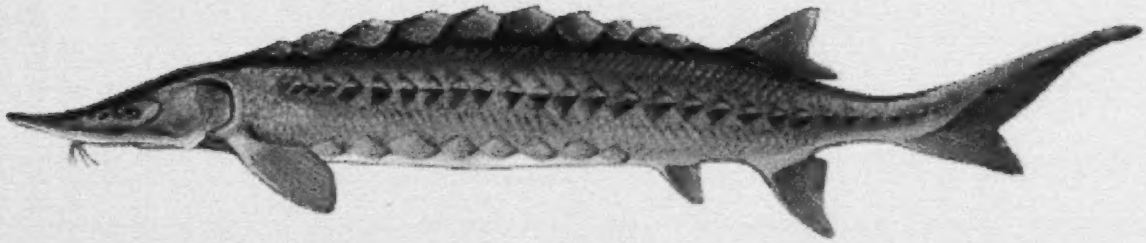


Figure 1. Atlantic Sturgeon, *Acipenser oxyrinchus* (courtesy USFWS).

Pigmentation is a brassy-tan to brown green on the back and sides, and white on the ventral surface. Colour usually darkens in adults during estuarine and fresh water residency to almost black on the dorsal surface. The scutes (hard, bony projections from the skin) are arranged in five rows, one dorsal, two lateral, and two ventral-lateral (Vladykov and Greeley 1963). When the sturgeon are young the scutes are high-ridged and razor sharp (Dadswell, personal observations, 2009). In older fish they are ridged but smooth. The body shape is fusiform, pentagonal in cross-section, and elongated with a heterocercal caudal fin (Figure 1). The mouth is inferior, and the snout is elongated and triangular in dorsal view. There are four barbels near the tip of the snout, and teeth are absent, except during larval stages (Snyder 1988).

The Atlantic Sturgeon can be distinguished from the only other east coast anadromous sturgeon, the Shortnose Sturgeon, *Acipenser brevirostrum*, by the longer, V-shaped snout, a larger number of scutes (four versus one, respectively) between the anal and caudal fins, preanal scutes in two rows as opposed to one, and a larger number of scutes (six to nine versus two) behind the dorsal fin (Page and Burr 1991). The two species only co-exist (in Canada) in the Saint John River, the only known Canadian locality for *A. brevirostrum* (Scott and Crossman l998). The range also overlaps with the freshwater Lake Sturgeon, *Acipenser fulvescens*, in the St. Lawrence River; the Lake Sturgeon being found as far downstream as the termination of freshwater (≈ Québec City), while the Atlantic Sturgeon may proceed upstream as far as Lac St. Pierre (Scott and Crossman 1998). Atlantic Sturgeon are larger (average 2 - 3 m in length and 100 - 200 kg in weight as opposed to 1 - 1.5 m and 5 - 40 kg for Lake Sturgeon), darker in colour, and have a longer, more V-shaped snout. Atlantic Sturgeon have fewer lateral scutes (24 - 35 as opposed to 29 - 42), but more behind the dorsal fin (six to nine versus zero), and between the anal and caudal fin (four versus one).

Spatial population structure and variability

A. o. oxyrinchus ranges along the Atlantic coast from northern Labrador to Florida (Figure 2) where it is known from a minimum of 135 collection sites (Gruchy and Parker 1978), at least six of which are in Canada. Adults spend much of their non-breeding time at sea, but close to shore. Extensive coastal migrations along the coastline (up to 1,500 km) have been recorded (Burkhead and Jenkins 1991). Some individuals in northern populations, such as those in the Gulf of St. Lawrence and the Bay of Fundy, may stay upstream in winter. Juveniles overwinter in freshwater, or move into brackish areas when temperatures drop in the fall, and some may spend several years in freshwater (Hoff 1980).

Table 1. Current status of known or postulated populations of Atlantic Sturgeon, *Acipenser oxyrinchus oxyrinchus*.

River	Status	Source
St. Lawrence River, Quebec	Historical population size unknown, but based on catch records in excess of 3,000 adults. Current breeding stock size is thought to be about 500 adults.	Caron *et al.* 2002
Gulf of St. Lawrence/Miramachi River – New Brunswick	Small spawning population may exist.	Cox 1893; McKenzie 1959; Dadswell 2006
Annapolis,, Avon, Shubenacadie, La Have, and St. Croix rivers – Nova Scotia	Small spawning population postulated to exist.	Vladykov and Greeley 1963; Leim and Scott 1966; NMFS 1998b; Dadswell and Rulifson 1994; Dadswell 2006
Saint John River, New Brunswick	Historical population size unknown, but based on catch records in excess of 11,000 adults. Current breeding stock size is thought to be at least 1000-2000 adults.	Dadswell 2006; DFO 2009A
Penobscot River – Maine	Small population of unknown size	Vladykov and Greeley 1963; ASSRT 2007
Estuarial complex of Kennebec, Androscoggin and Sheepscot rivers – Maine	Supported a small commercial fishery prior to 1988, a few adults and sub-adults have been collected in surveys between 2000 – 2005.	Squiers and Smith 1978, Squiers 2005; ASSRT 2007
Piscataqua River – New Hampshire	Extirpated	ASSRT 2007
Merrimack River – New Hampshire, Massachusetts	No evidence of a spawning population, although the estuary is used as a nursery area.	Kieffer and Kynard 1993; ASSRT 2007
Taunton River – Massachusetts, Rhode Island	Historically sturgeon spawned in the system, but spawning no longer occurs there, although it is used as a nursery area.	Tracy 1905; Burkett and Kynard 1993; ASSRT 2007
Thames River – Connecticut	Abundant prior to 1825 when construction of the Grenville Dam prevented spawning.	Whitworth 1996; ASSRT 2007
Connecticut River – Massachusetts, Connecticut	Extirpated	Savoy 1996; ASSRT 2007

River	Status	Source
Hudson River – New York	Spawning stock thought to have consisted of 6000-6800 females in the 1800s, depleted by exploitation in 1880s-1890s, and again in the period 1980-1990. Population declined by over 80% between 1977 and 1995. Sturgeon are still present and CPUE of juveniles shows a slight increase and provides evidence of successful spawning.	Secor 2002; Kahnle *et al.* 2005; Dadswell 2006, ASSRT 2007
Delaware River – New Jersey, Delaware, Pennsylvania	Historically supported the largest population on the Atlantic coast. Prior to 1890 upwards of 180,000 females were thought to spawn in the Delaware. The commercial fishery substantially reduced the population in the late 1800s, and again in the 1980s-1990s. CPUE declined by over 93% between 1991 and 2004. A remnant population of spawning adults is thought to remain.	Kahnle *et al.* 1998; Secor and Waldman 1999; Secor 2002, Dadswell 2006; ASSRT 2007
Chesapeake Bay and Tributaries (Potomac, Rappahannock, York, James, Susquehanna, Nanticoke rivers) – Pennsylvania, Maryland and Virginia	Historically common throughout Chesapeake Bay and its tributaries, upwards of 20,000 adult females may have inhabited the Bay and its tributaries. It is thought that a remnant population (low hundreds still exist based on captures of juveniles and the occasional adult.	Kahnle *et al.* 1998; Wharon 1957; Bushroe *et al.* 2005; ASSRT 2007
Albemarle Sound, Roanoke and Chowan/Nettoway rivers – North Carolina	Historically abundant in the Roanoke/Albemarle Sound system – probably 7200-10, adult females present prior to 1890. Ripe and running adults have not been captured since the 1990s, but YOY have been captured. Catch records indicate that recruitment has been in decline since 2000.	Kahnle *et al.* 1998; Armstrong and Hightower 2002; Secor 2002; ASSRT 2007
Pamlico sound (Tar and Neuse rivers) – North Carolina	Remnant population only (probably < 100 adult females)	ASSRT 2007
Cape Fear – North Carolina	Adult sturgeon have been observed running upstream in the fall, population size is unknown, but undoubtedly small.	Moser and Ross, 1995ASSRT 2007
Winvah Bay (Waccanmaw, Pee Dee and Sampit Rivers) – South Carolina	Historically present in most South Carolina River systems, but not known where spawning occurred. Estimated that 8000 spawning females were present prior to 1890, but since 1890 populations have been decimated. In the last two decades Atlantic Sturgeon have been observed in most South Carolina coastal rivers and a small spawning population may still exist in the Pee Dee River.	Collins and Smith 1997; Secor 2002; ASSRT 2007
Santee and Cooper Rivers – South Carolina	A small (<100 adults) population may still exist in the Santee River.	ASSRT 2007

River	Status	Source
Ashley River – South Carolina	Unknown if this subpopulation still exists.	ASSRT 2007
ACB Basin (Ashapoo, Combahee, and Edisto rivers) – South Carolina	A small subpopulation may spawn in at least two of the three rivers	Collins *et al.* 2000; ASSRT 2007
Broad Coosawatchie River – South Carolina	Not known if a subpopulation exists.	ASSRT 2007
Savannah River – South Carolina, Georgia	Small, reproducing subpopulation remains.	Collins and Smith 1997; ASSRT 2007
Ogeechee River – Georgia	Prior to the collapse of the fishery in the late 1800s the spawning population of sturgeon in Georgia rivers was thought to contain over 11,000 spawning females. Peak landings were also recorded in 1982, but since then subpopulations have been in decline in most Georgia rivers, including the Ogeechee. Spawning is still believed to occur in the Ogeechee, but the absence of age-1 fish in some years suggests this subpopulation is highly stressed.	Rogers and Weber 1995; Secor 2002; ASSRT 2007
Altamaha River – Georgia	This river supports one of the healthiest Atlantic Sturgeon subpopulations in the southeast. Between 300-400 adults were estimated to participate in spring spawning runs in 2003 and 2004; 1.5% of the historic spawning stock.	Secor 2002; Schuller and Peterson 2006; Secor 2002; ASSRT 2007
Satilla River – Georgia	Only four spawning adults have been collected since 1995.	ASSRT 2007
St. Mary River – Georgia, Florida	Extirpated	Rogers *et al.* 1994; Rogers and Weber 1995; Kahnle *et al.* 1998; ASSRT 2007
St. Johns River – Florida	No data to support spawning, but may serve as a nursery area.	Rogers and Weber 1995; Kahnle *et al.* 1998; ASSRT 2007

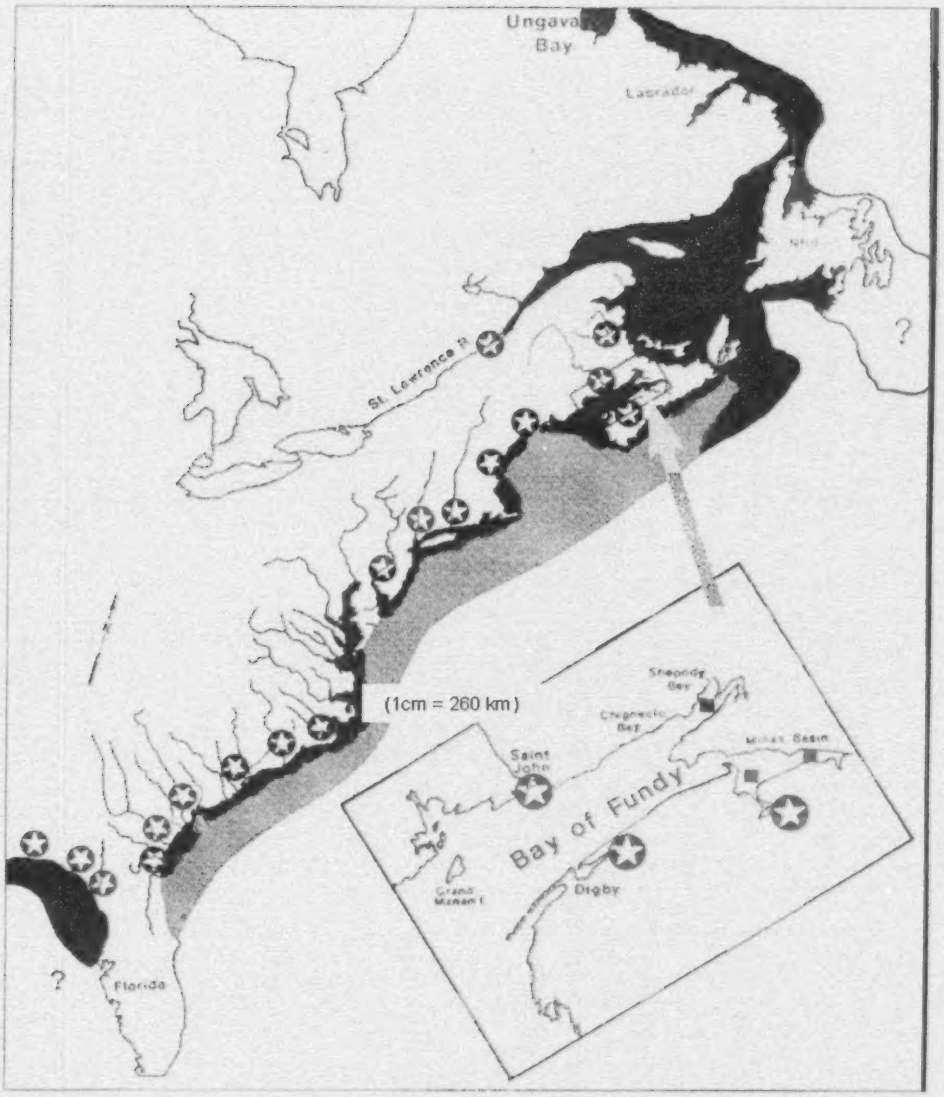


Figure 2. North American distribution of Atlantic Sturgeon. Stars indicate known and potential spawning populations, and squares summer concentration sites in the inner Bay of Fundy (insert) [adapted from Dadswell 2006].

Despite the apparently wide-ranging behaviour of the adults, mitochondrial DNA (mtDNA) analyses suggest some differentiation exists at a regional, and in some cases, population level (Waldman *et al.* 1966; Waldman and Wirgin 1998 Waldman *et al.* 2002; Wirgin *et al.* 2000). From 14 to 19 populations are currently recognized (NMFS 1998a), at least two of which are in the northern regional stock (St. Lawrence and Saint John rivers), which inhabit, and spawn in, Canadian waters. The mtDNA control region sequence (547 base pairs) results reported by Grunwald *et al.* (2008) indicated that fish collected from the St. Lawrence River estuary (N = 25) and the Saint John River (N = 66) differed significantly ($P < 0.001$) in the frequencies of three haplotypes resolved. Furthermore, King *et al.* (2001) found several private microsatellite DNA alleles both in the Saint John River and in the St. Lawrence River (when sampled well upstream of the estuary) and that the two areas showed significant allele frequency differences across six loci ($F_{ST} = 0.086$, $P < 0.001$). The Atlantic Sturgeon Status Review Team used all of the available data on hand to propose the listing of five distinctive population segments from a U.S. perspective (DPS – identified by their discreteness from other units and their "significance" to the species, Waples 1991). Populations of the St. Lawrence River estuary, however, were not included in the review, and the population in the Saint John River estuary was grouped with the DPS identified as Gulf of Maine (Saint John, Penobscot and Kennebec rivers' estuaries) [ASSRT 2007]. Grunwald *et al.* (2008) argued for nine DPSs across the Atlantic range based on their results which superseded the ASSRT review.

Designatable units

Putative designatable units (DUs) in the Atlantic Sturgeon were evaluated in light of COSEWIC's (2009) criteria of "discrete" and "significance". Based on their occupancy across three National Biogeographic Zones (Great Lakes and upper St. Lawrence River; Lower St. Lawrence River; Maritimes) Atlantic Sturgeon in Canada can be divided into three discrete units. In addition, for at least two of these areas (Middle St. Lawrence and Maritimes) there is evidence of genetic discreteness based on mtDNA and microsatellites as discussed under **Spatial population structure and variability**. Evidence indicating the significance of these discrete units is less compelling, but the two major spawning populations across the Canadian Range (St. Lawrence River and Saint John River) exist in quite distinct hydrological and climatological regimes suggesting that adaptive difference in life history, migration patterns, or other traits might exist. In addition, the loss of one of the two major spawning populations would clearly impact a significant portion of the range of the species in Canada. Accordingly, these observations suggest the existence of two DUs: St. Lawrence River and Maritime DUs. Although Atlantic Sturgeon may venture further upstream within the Great Lakes – Upper St. Lawrence River NFBZ, the presence of known spawning populations right at the boundary of the Great Lakes-Upper St. Lawrence and the Lower St. Lawrence River NFBZ (i.e., at Portneuf, Quebec) and the likelihood of free movement of individuals between the upper and lower St. Lawrence River does not merit recognition of a third DU at this time.

Special significance

There are 23 species in the family (Acipenseridae) recognized worldwide, most of which occur in Eurasia. The Atlantic sturgeon is one of five species of sturgeon found in North America (Scott and Crossman 1998), and the only species in North America that formerly had populations in Europe (Ludwig *et al.* 2001). Its sister species, *Acipenser sturio*, is found in rivers and the sea around the coast of southern Europe (Magnin 1962). Most sturgeon species have been severely impacted by human activity through exploitation, and habitat degradation and destruction. Many are now under stringent management regimes, are sea-ranched from hatchery-based facilities, or are being grown in aquaculture operations (Binkowski and Doroshov 1985). The Atlantic Sturgeon is one of the largest fishes occurring on the east coast of North America and the largest that enters freshwater (Scott and Scott 1988).

The Atlantic Sturgeon is a significant species both biologically and commercially. Biologically, it has been of interest to science with its ancestry leading back some 200 million years. Commercially, it is valued for its flesh, which is usually smoked and brings a high price per kg, and it may also be valued for caviar. The trade in sturgeon meat, caviar, and other products is international. Caviar is one of the most valuable fish product in the world and some Atlantic Sturgeon caviar is marketed in Canada (see http://www.ic.gc.ca/app/ccc/srch/nvgt.do?sbPrtl=&prtl=1&estblmntNo=234567094430&profile=cmpltPrfl&profileId=905&app=sold&lang=eng). In some species, caviar is worth up to $550/kg in legal markets MD (2003), and processed caviar can bring well in excess of $1,000/kg on the domestic market (Cites World 2001; Sibun 2007).

There is little or no written documentation of current sturgeon use by Aboriginal peoples in the Maritimes or Quebec, but the anecdotal information is vast (F. Caron, Wildlife Research Branch, Quebec Department of Wildlife and Parks, personal communication 2004; S Douglas, Department of Fisheries and Oceans, Moncton, New Brunswick, personal communication 2004). Archaeological evidence (see for example Anonymous 2002), and oral history dating back some 2,400 years, suggests that Atlantic sturgeon were important for food and other uses prior to the 20th century. This evidence, however, gives no idea as to quantity of fish exploited, nor information on the biology of the species except that at some archaeological sites sturgeon scutes and other body parts account for up to 70% of fish faunal remains (Anonymous 2002).

DISTRIBUTION

Global range

Atlantic Sturgeon occur in rivers, estuaries, nearshore marine environments and the continental shelf regions to at least 50 m depths along the Atlantic coast of North America (Stein *et al.* 2004). They range as far north as Ungava Bay, south along the coast of Labrador, into the Gulf of St. Lawrence, southward on the Atlantic coast to Florida and along the coast of the Gulf of Mexico (Smith 1985; Scott and Scott 1988). The current range is the same as the historical range in both Canada and the United States (Figure 2), but populations that once existed in the Baltic Sea of northern Europe are extirpated (Ludwig *et al.* 2002).

Canadian range

In Canada, Atlantic Sturgeon have been reported to occur as far north as the George River in Ungava Bay, and south along the Labrador coast at Hamilton Inlet, to the Gulf of St. Lawrence and upstream in the St. Lawrence River as far as Lac St. Pierre; and south along the coast of Nova Scotia and the Bay of Fundy (Vladykov and Greeley 1963; Leim and Scott 1966; Scott and Crossman 1973; Gruchy and Parker 1978). There are records from Newfoundland coastal waters, but none in freshwater (Scott and Crossman 1998). Perhaps only 10-20% of the species' range occurs in Canada (Figure 2).

Historically, specific, systematic sampling effort to record presence/absence in Canadian rivers has been sporadic and incomplete. It is not known if spawning ever occurred in rivers flowing into Ungava Bay or in Labrador (Colligan *et al.* 1998). In fact, there is no strong evidence to support spawning in Canadian waters other than the St. Lawrence River (Caron and Tremblay 1999; Hatin *et al.* 1998, 2002; Caron *et al.* 2002), and the Saint John River (Dadswell 1984; Dadswell *et al.* 1984; NMFS 1998b; Dadswell 2006). Spawning was thought to occur in the Miramichi (Cox 1893; McKenzie 1959; Dadswell 2006), and the St. Croix rivers (Dadswell 2006), but the current status of these populations is unknown. In summer, adults and juveniles are found in the Saint John River estuary, the Cumberland and Minas basins in the upper Bay of Fundy, and there are records from the Avon, Shubenacadie, LaHave and other rivers of similar size (Vladykov and Greeley 1963; Leim and Scott 1966; NMFS 1998b; Dadswell 2006). Dadswell and Rulifson (1994) also observed Atlantic Sturgeon in the Annapolis River, Nova Scotia during tidal power studies in 1986. There is some mixing of Atlantic Sturgeon from U.S. waters in the Bay of Fundy, but, as yet, no tagged fish from the St. Lawrence River have been captured in the Bay of Fundy (DFO 2009a).

In Canada, the species is known to spawn in only two areas (Saint John River and middle St. Lawrence River) and these were used to define two locations (*sensu* COSEWIC 2009) across the two DUs. These two locations were defined in terms of the potential for over-exploitation in commercial fisheries that operate in these areas (see **Threats and Limiting Factors** section). The calculations of EOs for the two DUs is somewhat complicated by the fact that during non-spawning periods, members of both DUs share some marine habitats. Accordingly, what follows is the maximum EO of both DUs, including some areas of overlap (see Table 2 and Figure 3). Following the COSEWIC guidelines (COSEWIC 2009) and excluding non-habitable terrestrial area, the extents of occurrence (EO) were estimated to be about 252,574 km^2 and 330,539 km^2 for the St. Lawrence River and the Maritimes DUs, respectively. These EOs include an area of 27,562 km^2 where the marine range of the DUs overlap with one another (Figure 3). The index of area of cccupancy, based on overlain 2 x 2 km^2 (1 x 1 km^2) grids, was estimated to be 104 km^2 (55 km^2) and 612 km^2 (429 km^2) for the St. Lawrence River and the Maritimes DUs, respectively (Table 2).

Table 2. Values for extent of occurrence (EO) and index of area of occupancy (IAO) in km^2 for Atlantic Sturgeon (*Acipenser oxyrinchus*). All units are in km^2. The values in parenthesis for EO represent the extent of overlap between the two DUs. Index of area of occupancy is for a 2 x 2 km^2 grid with the value for a 1 x 1 km^2 grid in parentheses.

Designatable unit	EO	EO minus terrestrial area	IAO
Lower St. Lawrence River	723,206 (48,642)	252,574 (27,562)	104 (55)
-Richelieu Rapids	14 (28)		
-Confluence of St. Lawrence and Chaudière rivers			12 (28)
-Saint Antoine de Tilley			29 (48)
Maritimes	512,799 (48,642)	330,539 (27,562)	612 (429)1

[1]Saint John River from Mactaquac Dam to confluence mouth

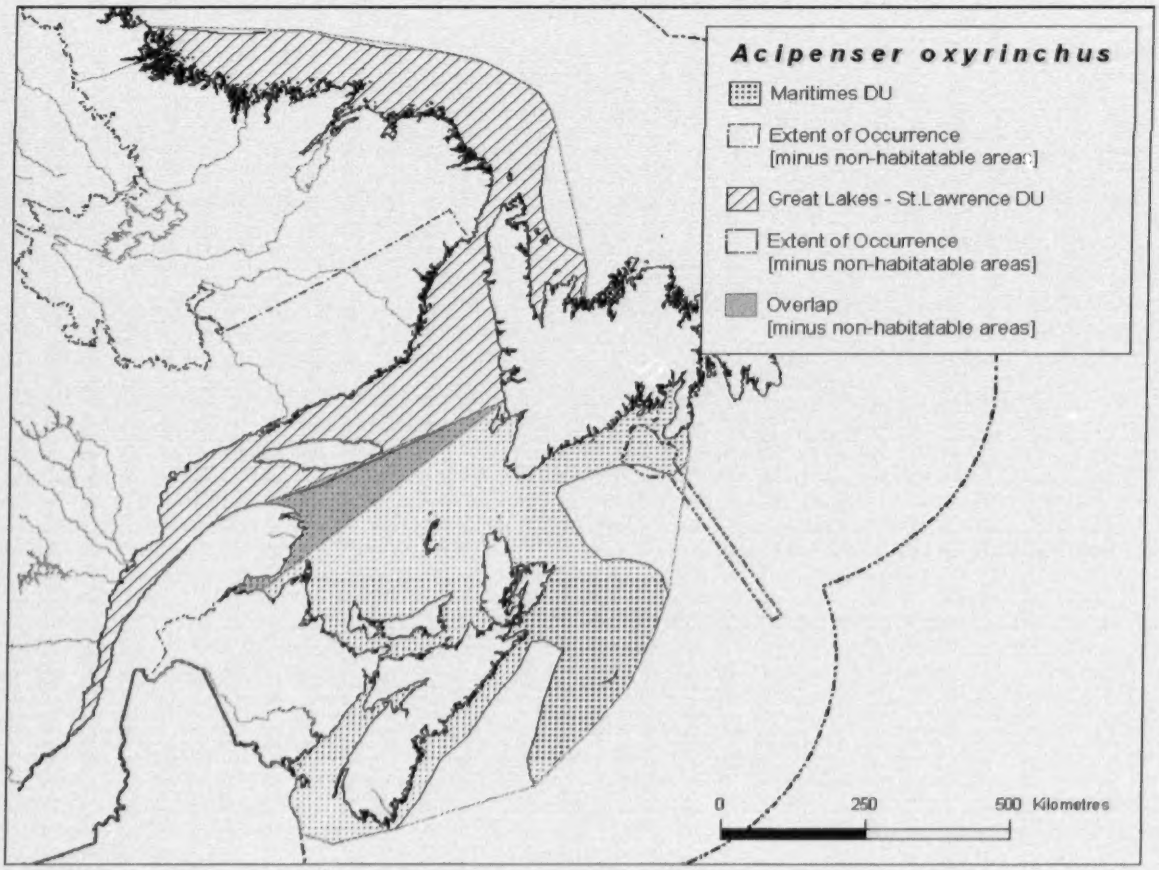


Figure 3. Extents of occurrence for St. Lawrence River and Maritime DUs of Atlantic Sturgeon (*Acipenser oxyrinchus*). The narrow rectangular outline and the easternmost dashed line represent fishery zones for various marine fishes.

HABITAT

Habitat requirements

Little is known of the ecology of Atlantic Sturgeon in the northern part of the range (Caron *et al.* 2002), but important habitats for Atlantic Sturgeon appear to be a river with access to the sea, preferably with deep channels; an estuary with relatively warm, mesohaline conditions (5 - 25 ppt) and a coastal shelf region (Dadswell 2006). Vladykov and Greeley (1963) speculated that Atlantic Sturgeon spawn in freshwater over rocky-gravel substrate in 1 - 3 m deep water with a strong current, and also under waterfalls and in deep pools with hard, clay bottoms. Research in Florida (Sulak and Clugston 1998; Fox *et al.* 2000), and Mississippi (Heise *et al.* 2004) demonstrated that during spawning, adult Atlantic Sturgeon will select regions of hard bottom substrate and strong currents. Caron (1998), and Hatin *et al.* (2002) identified three potential spawning

sites in the fluvial estuary of the St Lawrence River between Trois-Rivières and Québec City (Figure 4). Physical characteristics varied between the three sites; bottom topography at the Richelieu Rapids site varied from 20 - 23 m in depth over rock and bedrock with some sand and clay. The surface was turbulent with water velocity varying with tides (0.25 m/sec to 2.2 m/sec). Sturgeon were located at this site at depths of 10 - 23 m and water temperatures of 20.6 to 22.8 °C (Hatin *et al.* 1998, 2002). The second site at the confluence of the St. Lawrence and Chaudière rivers had similar bottom topography and substrate, but fish were found at greater depth (14 - 60 m) (Hatin *et al.* 2002). At the third site (Saint-Antoine-de-Tilley) fish were located at depths of 6 - 22 m (Hatin *et al.* 2002). The total length of each of the three identified potential spawning areas is less than 3 - 4 km (Hatin *et al.* 2002).

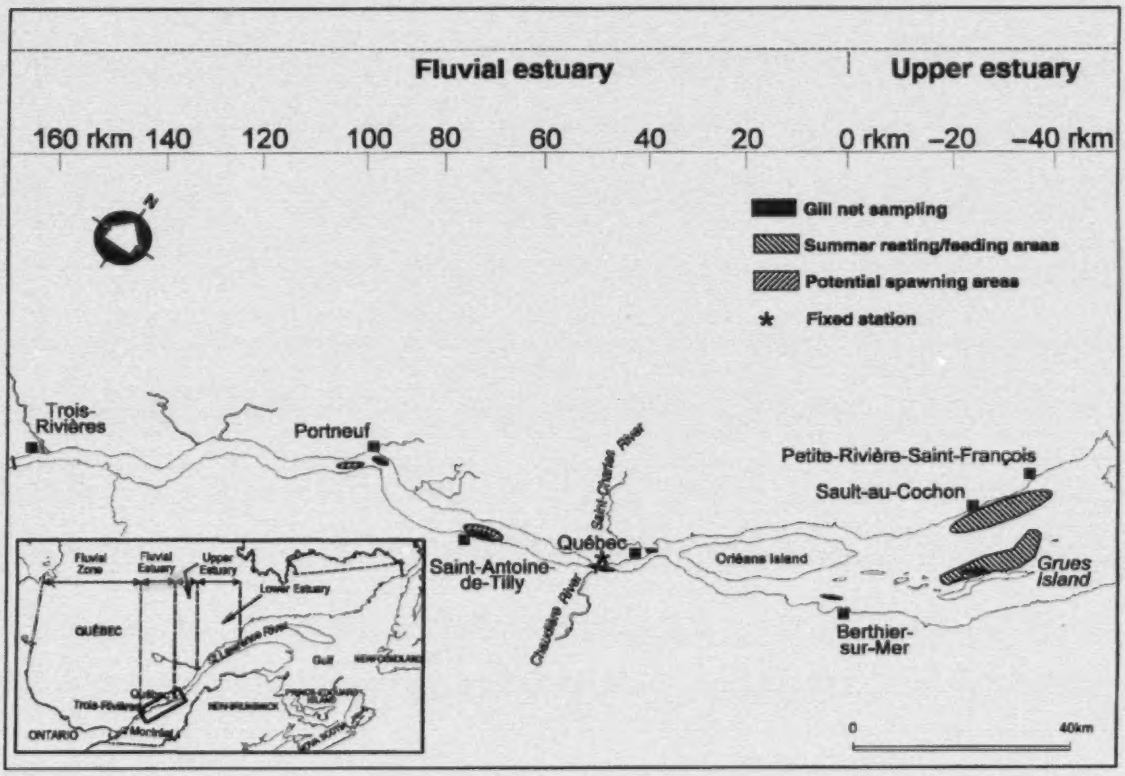


Figure 4. Atlantic Sturgeon aggregation and potential spawning site areas identified in the St. Lawrence River (adapted from Hatin *et al.* 2002).

Hatin *et al.* (2002) also identified three other areas in the fluvial and upper estuaries that may be of importance in the life cycle of the Atlantic Sturgeon. The St. Charles River estuary is a deep bay in the Québec City harbour area with clay substrate and low water velocity. Adult sturgeon appear to feed in this area from mid-May to late August, before concentrating at sites downstream in the upper estuary (Hatin *et al.* 2002). The Traverse du Milieu Channel, and the northern channel, between Sault-au-Cochon and Petite-Rivière-Saint-François appear to be other major aggregation sites where the sturgeon feed in late summer before moving further downstream (Hatin *et al.* 2002). These may be important transition areas for the transfer from fresh to salt water (Wooley and Crateau 1985) as the salinity in this sector varies from 0.2 to 5 ppt with the tidal cycle and the substrate is mainly clay (Gagnon *et al.* 1993). Adults probably winter downstream in the lower estuary or the Gulf of St. Lawrence (Hatin *et al.* 2002). Guilbard *et al.* (2007) also indicated that areas of transition between freshwater and saltwater, beginning about 40 km downstream of Québec City, are very important feeding areas for age 0 to sub-adult Atlantic Sturgeon.

Because the area of coastal shelf is relatively unlimited for the present estimated size of the adult population, and use of riverine spawning sites is of short duration (Sulak and Clugston 1998; Hatin *et al.* 2002), the probable limiting factor for each river population is the size of the spawning areas as well as areas of mesohaline, juvenile nursery habitat. Although areas utilized by young-of-the year and juveniles have yet to be delineated, rivers with large mesohaline estuaries like the St. Lawrence, the Saint John, the Hudson and the Delaware rivers have, or had, large, commercially important populations. Smaller rivers, like the Annapolis River in Nova Scotia, and the Miramichi River in New Brunswick may have had, or may have, distinct populations, but more study is required to verify this (Dadswell and Rulifson 1994).

Habitat trends

Atlantic Sturgeon are vulnerable to a variety of habitat threats because they use rivers, estuaries, bays and the ocean at various times in their life cycle. Since the beginning of European settlement habitat loss and degradation resulting from human activities have presented problems for the species. Dam construction and operation have led to the inaccessibility of important spawning habitats; dredging, waste disposal and pollutants have led to water quality modifications (siltation, decreased dissolved O_2, contaminates) that have left many rivers unsuitable to support many fishes, including sturgeon (*see* Colligan *et al.* 1998). For instance, the construction of the Mactaquac Dam on the Saint John River in 1969 altered the downstream flow regime and blocked access to upriver areas that were probably used by Atlantic Sturgeon. It is difficult to assess the impact of such factors on habitat quality trends, particularly since the mesohaline nursery region is widespread on the Atlantic coast and juveniles from one river may use nursery areas in adjacent estuaries (Savoy and Pacileo 2003).

Although upstream portions of the Saint John River and the region around Saint John are under heavy influence of residential and industrial development, water quality appears to be relatively good (see http://www.gnb.ca/0009/0371/0013/English/SaintJohn.pdf). In addition, the mesohaline region in most Canadian rivers is relatively unpolluted, especially in the Maritimes (DFO 2009a). Pollution of the St. Lawrence River and estuary is being alleviated through various provincial and federal initiatives and general water quality, although highly variable spatially, was recently rated as "intermediate to good" (State of the St. Lawrence Monitoring Committee 2008). In the United States many rivers were blocked at tidehead (e.g., Kennebec and Susquahanna rivers) and many had badly polluted estuaries (Delaware, Hudson rivers), but with improved environmental awareness since the 1960s the amount of habitat available to Atlantic Sturgeon is increasing. Improved conditions on the Delaware River have lead to increased fish populations there (Chittenden 1976; Lazarri *et al.* 1986) and during 1999, the Augusta Dam was removed from the Kennebec River in Maine, allowing anadromous fishes access above tidehead for the first time since 1837 (Dadswell 2006). Improvement of estuarine habitat is occurring in Canada following more stringent adherence to environmental laws (St. Lawrence Centre 1996; Dadswell 2006).

Habitat protection/ownership

Little (or none) of Atlantic Sturgeon habitat is in protected areas. It is possible there are Atlantic Sturgeon present in some of the National Parks in the Maritimes that enclose estuaries (e.g., Kougibouguac Park near the Miramichi River), but to date Atlantic Sturgeon have not been recorded there. Habitat protection is provided for fishes by the Canadian *Fisheries Act*.

BIOLOGY

General

The general life history pattern of the species is that of a large, long-lived, late maturing, estuarine-dependent, anadromous species. Details of the life history may vary latitudinally, but the general pattern is that of an annual spring migration to freshwater to spawn near the fall line of rivers not far above the marine-freshwater demarcation and a return to the marine environment following spawning. Life history characteristics across the range have been reviewed by several authors (see NMFS 1998b), but the situation in Canadian waters has not been well documented. Recent studies conducted in the St. Lawrence River by Caron, Fortin and Hatin (e.g., Caron *et al.* 2002; Hatin *et al.* 2002; Hatin and Caron 2003; Guilbard *et al.* 2007) have provided new insights into the biology of this species in Canada.

Reproduction

Sexual maturation

The age at which sexual maturation occurs in Atlantic Sturgeon varies according to gender and latitude (Smith 1985; Caron *et al.* 2002). Males mature earlier and at a smaller size than females. In the St. Lawrence River, male sturgeon first mature at 16 - 24 years of age, at a size of approximately 150 cm fork length (FL), and a weight of 36 kg. Females reach maturity at an age of 27- 28 years, at a size of 180 - 200 cm FL, and a weight of 64 kg (Scott and Crossman 1998; Caron *et al.* 2002). More southerly populations mature at a younger age. In the Hudson River, males mature at 11 - 12 (mean FL 162 cm) years of age, and females at 18 - 19 years (Dovel and Berggren 1983). In the Suwannee River, Florida, males mature at 7 - 9 years of age (110 - 120 cm FL), and females at 8 - 12 years (120-150 cm FL; Huff 1975). Caron *et al.* (2002) suggested that size of fish may be more important than age in triggering maturation.

The age structure of Atlantic Sturgeon in the Saint John River has not been determined. Given their intermediate geographic location, it might be reasonably assumed that growth rates of Atlantic Sturgeon in the Saint John River are between those of the St. Lawrence River and those of the Hudson River. Given the minimum ages of maturity cited above and that Atlantic Sturgeon have been recorded as old at 60 years (Scott and Crossman 1998) and the distribution of ages of sturgeon from the Saint John River (Figure 8), it is estimated that the generation time is about 40 years.

Sex ratio

Information on the ratio of males to females in Canadian waters is incomplete. One might expect a higher female to male ratio in older fish if, as for other sturgeons, the females live longer, but no age specific studies are available. Atlantic Sturgeon have been recorded to reach a maximum age of 60 years (Scott and Crossman 1998). Dadswell (1979) indicated that the male to female ratio was in the order of 1:1 for juveniles, but 1:2 for adult Shortnose Sturgeon in the Saint John River, which seems to agree with the results of sampling of the commercial catch of Atlantic Sturgeon, from the Saint John River (DFO 2009a). In Lake Sturgeon the sex ratio is more or less 1:1 at birth, but following maturation, begins to widen in favour of the females (Mosindy and Rusak 1991; Fortin *et al.* 1993) due to their greater longevity (Probst and Cooper 1954; Dumont *et al.* 1987).

Caron and co-workers (2002) captured 118 males and 24 females during a three year study of spawning fish in the St. Lawrence River using gangs of different sized gill nets (ratio of M:F of 5:1); however, the sex-ratio of sub-adults in the commercial fishery appears to be close to 1:1 (Trencia *et al.* 2002), but for larger sturgeon (>165 cm FL) was 1:1.3. In other areas to the south, the results have been varied as well, but tend to a ratio slightly skewed in favour of females in rivers where the fish have not been as severely impacted by exploitation, impoundments and pollution. Huff (1975) concluded that in the Suwannee River, Florida, sex ratio did not significantly vary from 1:1. Studies

of the commercial landings in South Carolina (SC) between 1978 -1982 found male to female sex ratios of 1:2 to 1:4 (Smith *et al.* 1984). Fox *et al.* (2000) found a M:F ratio among spawning Atlantic sturgeon of 3:1 in the Edisto River, SC, and similar results have been noted in other southern river systems (Van Eenennaam *et al.* 1996; Collins *et al.* 2000). Where populations have experienced serious decline; however, no ripe females are taken in some years (e.g., Hudson River, Mohler and Fletcher 1998).

Caron *et al.* (2002) indicated that the high ratio of males in their sample may be a result of a combination of factors: the apparent population decline between 1967 and 1975 (see **Population Sizes and Trends**); the spawning runs now consist predominately of earlier maturing males, and different behaviour, life cycle, and catchability of the larger, older females. Males tend to precede the females during the spawning migration moving upstream to spawning sites up to a week earlier (Fox *et al.* 2000). Females tend to stay in freshwater for shorter periods of time and move over smaller areas (Smith 1985; Sulak and Clugston 1998; Foxe *et al.* 2000; Hatin *et al.* 2002). In addition, females are older at first spawning and have a longer spawning interval (see below), and there may not be as many on the spawning sites.

Fecundity

Long periods of reproductive quiescence are common among sturgeon of all species (Vladykov and Greeley 1963; Dadswell 1979); Atlantic Sturgeon are no exception, exhibiting intervals longer than a year, or more, between reproductive periods. In South Carolina females spawn at intervals of 3 - 5 years, males, at 1 - 5 year intervals (Smith 1985; Fox *et al.* 2000). Recent studies by Caron *et al.* (2002) in the St. Lawrence River tend to indicate similar periodicity there; intervals were found to be three or more years for both sexes.

Because of their large size, female Atlantic Sturgeon are extremely fecund. Vladykov and Greeley (1963) reported that a female from the St. Lawrence River, weighing 148 kg, had ovaries weighing 41.4 kg, which contained an estimated 3.7 million eggs. Female gonad weight varies from 12 - 25% of the total body weight (Smith 1907; Huff 1975), and mature females may contain between 800,000 and four million eggs depending on size and age (Ryder 1890; Smith 1907; Van Eenennam *et al.* 1996). The potential fecundity of a 350 kg female, like the one captured in the Saint John River in 1924, might be seven to eight million eggs.

Spawning and early growth

Spawning in the St. Lawrence River occurs in June and July at temperatures of 16 - 20 °C (Hatin *et al.* 2002), after which adults migrate downstream to the estuary or move into the ocean. The eggs are slightly adhesive and attach to the bottom substrate (Sulak and Clugston 1998). Hatching of the eggs occurs in 3 - 7 days at water temperatures of 18 - 20°C (Smith 1985). The fry hatch at a length of 8 - 10 mm (Snyder 1988) and are nourished by their attached yolk sac. At first, the young are benthic and cryptic, but soon move onto soft bottom habitats in fluvial and estuarine conditions

(Chan *et al.* 1997; Dadswell, unpubl. data, 2009). Juveniles grow rapidly, reaching 10 cm in 2 - 4 months and 20 - 35 cm by the end of their first year of growth (Smith 1985; Sulak and Clugston 1998). In Canada, juveniles reach 50 cm at age 3 - 5 and 100 cm at age 10 - 15 years (Dadswell, unpubl data, 2009). Growth in the Saint John River, NB is about twice as fast as growth in the St. Lawrence River (Magnin 1962; Dadswell unpubl. data, 2009). Juveniles migrate to sea at a size of 80 - 120 cm, although in the St. Lawrence River perhaps only a portion migrate past the lower estuary (Hatin *et al.* 2002).

Survival

There is no information on natural mortality, but these large, slow growing, late-maturing fish may live several decades (Gilbert 1989). Age estimates for slow growing, long-lived species in colder water systems are problematic as the generally accepted method of counting growth rings from cross-sections of the right pectoral fin ray (Brennan and Caillet 1989) may underestimate true age and age-at-maturity (Paragamian and Beamesderfer 2003). The age of senescence is not known, but Boreman (1997) estimated the average age at which 50% of maximum lifetime egg production is achieved to be 29 years; however, the maturation rates used in the model were for southern populations for the St. Lawrence River populations this might be extrapolated to an age of approximately 40 years.

Studies on the anadromous White Sturgeon, *Acipenser transmontanus*, of the Pacific coast indicate that the instantaneous natural mortality rate is in the order of 0.05 for fish of the lower Fraser River and 0.06 in the upper Columbia River (Galbreath 1985; Ptolemy and Vennesland 2003). Since the life history and ecology of the two are very similar this may be a reasonable figure to use as a starting point for population models for Atlantic sturgeon.

Physiology

Temperature effects

Atlantic Sturgeon growth varies inversely with latitude; fish from northerly populations grow more slowly than fish from southern populations (NMFS 1998b). Hardy and Litvak (2004) reared Shortnose Sturgeon and Atlantic Sturgeon at different temperatures (13, 15, 18, 21°C) post-hatch and found that newly hatched Atlantic Sturgeon, were smaller in size, more efficient at utilizing yolk and reached developmental stages sooner than Shortnose Sturgeon reared at the same temperatures (13 and 15°C). Within each species, decreasing temperature delayed yolk absorption, escape initiation, time to reach maximum size, and time to 100% mortality. However, yolk utilization efficiencies and the size of larvae were independent of rearing temperature for both species. These results suggest that even as temperature drives metabolic processes to speed up development, these two species are still extremely efficient at transferring yolk energy to body tissues.

Salinity tolerance

Juvenile Atlantic Sturgeon remain in riverine or estuarine environments for up to six years, and this may be related to salinity tolerances of younger fish. No studies are documented for this species, but Jarvis *et al.* (2001) examined the effect of salinity on growth of juvenile Shortnose Sturgeon grown in culture and found that weight gain and feed conversion rate (FCR) decreased with increasing salinity. Fish reared at 0 ppt showed significantly more weight gain and greater FCR than the fish raised at all other salinities tested (0, 5, 10, and 20 ppt). Fish reared at 20 ppt exhibited the poorest growth.

Exercise

Kieffer *et al.* (2001) examined the physiological responses to exercise of Atlantic Sturgeon and Shortnose Sturgeon, and found that Shortnose and Atlantic Sturgeon do not exhibit the physiological responses to exhaustive exercise typical of other fish species. They may possess behavioural or endocrinological mechanisms that differ from those of other fishes and that lead to a reduced ability to respond physiologically to exhaustive exercise.

Oxygen

Collins *et al.* (2000) suggested that deterioration in water quality may affect nursery production of juvenile sturgeon; Secor and Nicklitschek (2001) suggested that absence or reduced populations of both Shortnose and Atlantic Sturgeon were a result of low oxygen levels.

Movements/dispersal

Migrations are an essential component of the life history of Atlantic Sturgeon. Adult sturgeon migrate into estuaries and rivers in the autumn (August - October) or in the spring (May-June) preceding reproduction (Vladykov and Greeley 1963; Smith 1985; Hatin *et al.* 2002). Adults often overwinter in deep channels and pools in rivers and estuaries downstream of the spawning sites (Dovel and Berggren 1983; Dadswell, unpubl. data, 2009). Males tend to precede the females during the spawning migration moving upstream to spawning sites up to a week earlier (Fox *et al.* 2000). Females arrive as the temperature reaches 13-17°C (Murawski and Pacheco 1977; Hatin *et al.* 2002). Juveniles move inward and seaward in estuaries in response to season and salinity. Large juveniles and adults migrate along the east coast of North America (Vladykov and Greeley 1963). Atlantic Sturgeon tagged in the St. Lawrence River estuary, were recaptured on the coasts of Newfoundland and Nova Scotia (five recaptures; Vladykov and Greeley 1963). Atlantic Sturgeon, tagged as juveniles in the Hudson River, were recaptured as far south as North Carolina (after three to five months) and as far north as Massachusetts (61 recaptures; Dovel and Berggen 1983). Hatchery juveniles released in the Nanticoke River, Maryland were recaptured as far south as Pamlico Sound, North Carolina, within a year (Secor *et al.* 2000). Atlantic

Sturgeon, tagged in the sea off North Carolina, were recaptured as far north as Long Island, NY (Murawski and Pacheco 1977). Most studies suggest that large juveniles and non-spawning adults in the sea migrate south to Virginia and North Carolina in fall and winter, returning north in spring and summer as far as the Bay of Fundy and the Gulf of St. Lawrence (Waldman *et al.* 1996). Atlantic Sturgeon captured in the winter off North Carolina ranged from 50 – 225 cm FL (Holland and Yelverton 1973), while those captured off New Jersey ranged from 97 – 219 cm FL (Johnson *et al.* 2007).

Tag recaptures indicate that Atlantic Sturgeon of 100 - 150 cm can travel distances of 600 - 1,400 km in periods of 65 - 307 days, which suggests they can migrate up to 10 km/day (Vladykov and Greeley 1963; Murawski and Pacheco 1977; Dovel and Berggen 1983).

Except for juveniles that congregate in their natal estuary, and adults returning to spawn, Atlantic Sturgeon are generally spread out along the east coast of North America and over the continental shelf. In the St. Lawrence River estuary there is an aggregation of juveniles and adults between Trois-Rivières and Ile d'Orléans (Vladykov and Greeley 1963; Caron 1998), and large juveniles and adults downstream from Ile d'Orléans (Caron *et al.* 2002). Hatin *et al.* (2007) used sonic tagging to follow age 2 sturgeon in the St. Lawrence River estuary in the vicinity of Ile d'Orléans and some 50 km downstream and recorded summer home ranges of 1- 8 km^2, but areas of the greatest used were generally les than 1 km^2. Juvenile sturgeon moved up to 13.5 km in a single day. In the Saint John River, NB, there are known aggregations of juveniles during summer in the Long Reach region of the estuary, and adults at the mouth of Washdemoak Lake and Grand Lake in fall and winter (Rogers 1936; Dadswell, personal observation, 2009).

An aggregation of juveniles and adults occurs during summer in the Minas and Cumberland Basin regions of the inner Bay of Fundy (Dadswell *et al.*1984; Wehrell 2005), along the Atlantic Bight in spring and fall (Waldman *et al.* 1996; Johnson *et al.* 2007), and off North Carolina in winter (Holland and Yelverton 1973). Adult Atlantic Sturgeon have, however, been captured as far north as Labrador (Scott and Scott 1988), as far out to sea as Georges and Browns Banks (Bigelow and Schroeder 1953) and as far south as French Guiana in South America (Vladykov and Greely 1963).

Nutrition and interspecific interactions

Atlantic Sturgeon prey on benthic organisms, feeding by means of a suctorial mouth and a vacuum created by the buccal cavity. Young sturgeon live over a soft bottom and prey on worms, crustaceans and molluscs. Vladykov and Greely (1963) reported that in the St Lawrence River, freshwater prey of juveniles consisted of aquatic insect larvae (mayflies, chironomids), amphipods, isopods and oligochaete worms, and in brackish water, decapods (*Crangon* spp.), amphipods, isopods, gastropods and polychaete worms. Adults feed on polychaete worms, shrimp, amphipods, isopods and small fish, especially the sand lance, *Ammodytes* spp., (Vladykov and Greeley 1963; Johnson *et al.* 1997). There appears to be a specialization in diet towards soft-bodied

organisms; they feed on whatever species are available in the local benthos (Appy and Dadswell 1978; Armitage and Gingras 2003). During spawning migrations adults cease feeding and only resume when spawning is completed (Murawski and Pacheco 1977).

Little is known about predators of Atlantic Sturgeon, although it may be preyed on (and even killed) by the Sea Lamprey, *Petromyzon marinus* (Scott and Crossman 1998). Larger fish are not likely to be preyed on by other species, but the eggs and young would certainly be at risk.

Behaviour/adaptability

Millions of years of evolution have presumably specifically adapted Atlantic Sturgeon to the large river systems of eastern Canada and the U.S. This is an opportunistic species and their size and behaviour allow them to take advantage of widely scattered seasonal resources, but the long lifespan also suggests they may have a limited ability to adapt to rapid environmental perturbations.

POPULATION SIZES AND TRENDS

Search effort

There is a lack of detailed Atlantic Sturgeon fisheries survey information for most regions (Dadswell 1984, 2006). Reliable population estimates and trends in abundance for this species in Canadian waters are non-existent. Breeding populations are known from the St. Lawrence and Saint John rivers, and possibly in other rivers tributary to the Gulf of St. Lawrence (Miramichi River), the Bay of Fundy (Avon and Annapolis rivers of Nova Scotia (see **Distribution**). Very little is known of the species along the Labrador coast except that Atlantic Sturgeon has been reported from Hamilton Inlet and the Hamilton River, and possibly the St. George River in Ungava Bay (Gruchy and Parker 1978; Scott and Crossman 1998; NatureServe 2009). There may be spawning populations in some rivers of Labrador (Scott and Scott 1988), and along the north shores of the Gulf of St Lawrence (Vladykov and Greeley 1963), New Brunswick and Nova Scotia, Cape Breton Island, the Atlantic Coast of Nova Scotia, and the larger rivers within the Bay of Fundy, but these areas have not been systematically surveyed for Atlantic Sturgeon (Dadswell 1996). No population estimates were conducted on Atlantic Sturgeon in Canada prior to recent work in the St. Lawrence River estuary (Caron *et al.* 2002). Consequently, there is no evidence other than commercial landing information to indicate population trends.

Abundance and trends

The two known Canadian populations, the St. Lawrence and Saint John rivers, have supported commercial fisheries for which landings data are available. In the case of the Saint John River this goes back to the 1880s and in the St. Lawrence River to the 1930s (Figures 5 and 6). There have been two periods of major exploitation of Atlantic Sturgeon on the Atlantic coast, one during the 1880s - 1890s, and another during the 1980s - 1990s (Smith 1985; Secor 2002; Dadswell 2006; Johnson *et al.* 2007). In both cases, the history was similar; following each period of large catches, landings declined dramatically.

Maritimes DU (Saint John River)

When the Saint John River population was fished during a six-year period in the 1880s the recorded catch was about 530 metric tons (t) (Figure 5; Rogers 1936). Assuming an average of 50 kg for each sturgeon the catch represents about 11,000 adults over the six year period or ~ 1,800 fish per year (Dadswell 2006). When the fishery re-opened after a seven-year hiatus, the catch reached about 23 t (≈ 460 adults) in the first year, and within five years crashed again. After another one-year hiatus the landings (Figure 5) increased over a four-year period to less than 5 t annually and for the next 30 years averaged in the neighbourhood of 4 t with a downward trend. The catch bottomed out again, but within three years was up to 4 t, then 5 t, then declined rapidly to less than 1 t annually within five years. From 1940 through 1960 the landings slowly increased to slightly over 5 t, decreasing again to about 2 t by 1969. From 1969 through 1990, the oscillating catch history was repeated, with catches slowly rising to over 20 t annually, followed by decline (Figure 5), with a peak catch of 80 t in 1994. The 1994 catch was followed by a sharp decline to a level of 2 t and since that time has remained modest levels (200-300 fish annually), owing to marketing problems and not availability of fish (Dadswell 2006; DFO 2009a).

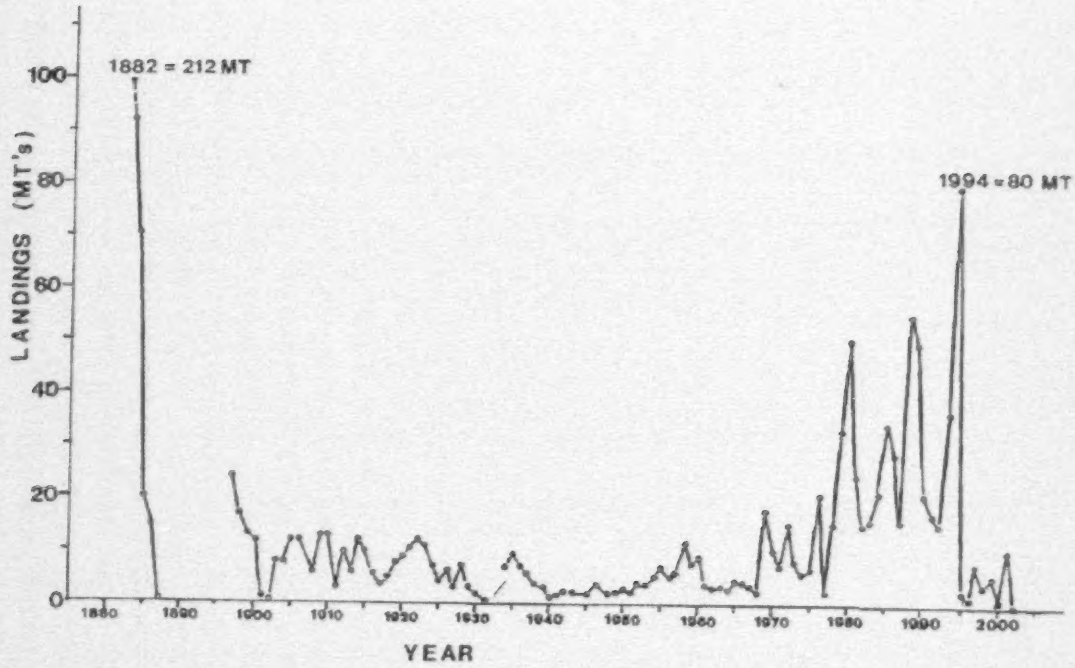


Figure 5. Commercial landings of Atlantic Sturgeon in the Saint John River, New Brunswick, from 1882 - 2002 (from Dadswell 2006; DFO 2009b). Landing statistics from 2004 - 2009 were not available at the time of writing.

Although records of landings for Atlantic Sturgeon caught in the Saint John River date to 1895, the record for the period 1895 - 1975 is widely variable and fluctuations in catch during this period are thought to more reflect fishing effort, location and market demand rather than abundance (DFO 2009a). It is also thought that landings were under-reported from 1965 - 1985, but since 1985 legal requirements to provide catch and effort information have resulted in more accurate reporting. In the Saint John River, where there is a minimum size limit of 122 cm total length, catches would translate to about 200 - 300 adult fish annually.

During the 1970s while working on Shortnose Sturgeon in the Saint John River, Dadswell (1979) found that juvenile Atlantic Sturgeon were about equally abundant to Shortnose Sturgeon in the region of their preferred habitat (salinity 5 - 25 ppt). Since the Shortnose Sturgeon population was approximately 100,000 individuals (juveniles and adults) it is possible that the total population size of Atlantic Sturgeon in that river was similar. Recent mark-recapture studies of tagged individuals (juveniles and sub-adults) in the Minas Basin suggest that they likely occur in the thousands in the Bay of Fundy, but the origins of these fish is not currently known, and they could be a mix of several populations (DFO 2009a) including fish from rivers outside Canada.

Length, weight, and sex data were collected from the commercial catch on the Saint John River in 1998 and 1999, and 2007 and 2008 and the results (Figure 6) indicate a similar size composition between the two time periods (DFO 2009a). A Von Bertalanffy relationship (fitted using the size at age curves from the St. Lawrence River population based on Magnin (1964)) indicated that a broad age distribution of spawners occurs in the Saint John River population with at least 20 age classes represented (Figure 7, 8).

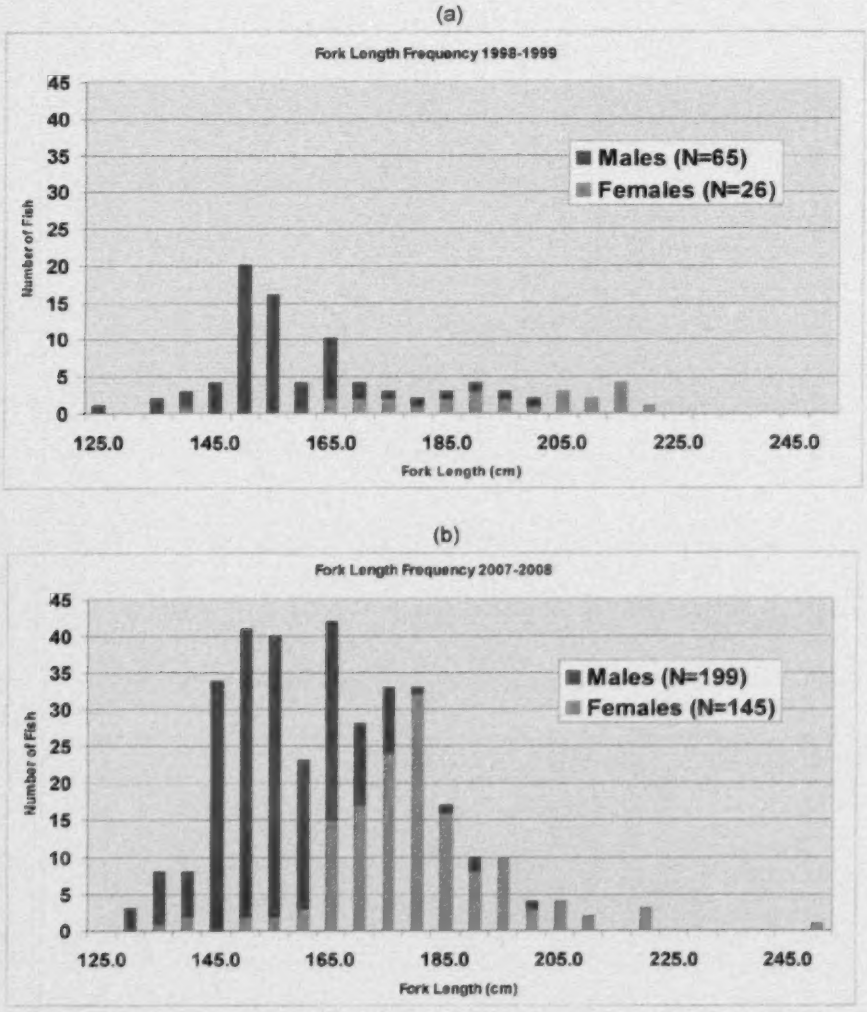


Figure 6. Length frequency distributions of the commercial catch of male and female Atlantic Sturgeon in the Saint John River for the years (a) 1998 and 1999, and (b) 2007 and 2008 (from DFO 2009a).

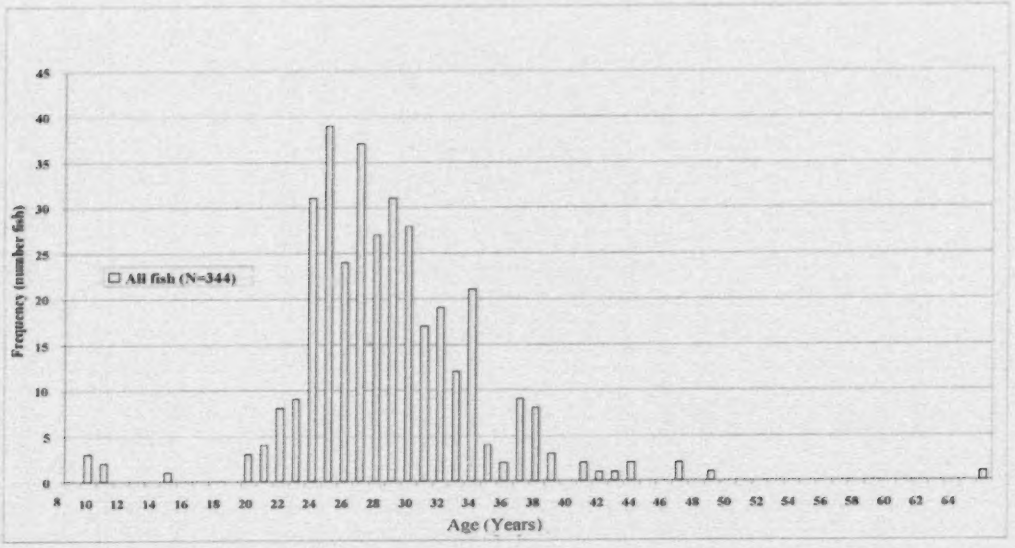


Figure 7. Estimated age structure of Atlantic Sturgeon captured in the 2008 commercial harvest on the Saint John River using Von Bertalanffy data from Magnin (1964) for the St. Lawrence River (Linf = 314.7, t0 = -0.7542, K = 0,0315). From DFO (2009a).

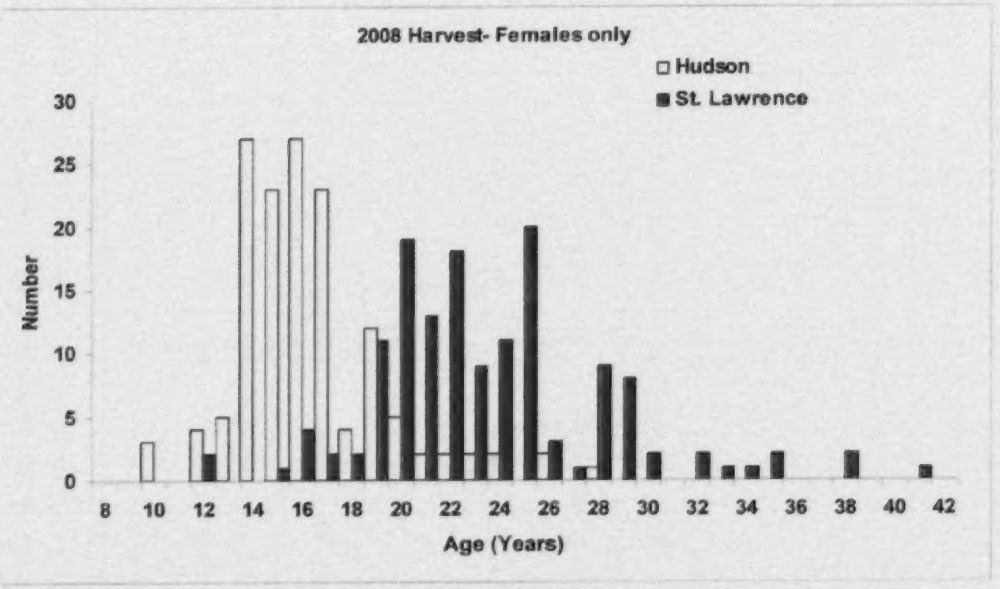


Figure 8. Estimated age structure of female Atlantic Sturgeon captured in the 2008 commercial harvest on the Saint John River using growth information from the St. Lawrence River population to the north and the Hudson River population to the south (from DFO 2009a).

Dadswell (2006) postulated that because the Saint John and Hudson river estuaries are approximately the same size, the Atlantic Sturgeon population sizes within them may be comparable. Research and commercial catches of spawning adults in the Hudson River varied from 200 - 350 adults annually during the 1990s (Bain 1994; Dadswell 2006). Since adults spawn every three to five years in the Hudson (Van Eenennaam *et al.* 1996; Bain 1977), the total adult population was estimated to be in the order of 1,000 - 2,000 individuals. Growth rates in the Saint John River probably fall between those reported for the Hudson River and the St. Lawrence River (DFO 2009a), and the harvests reported in the 1990s are similar to those reported for the Hudson, which could suggest (as did Dadswell 2006) that similar-sized populations once existed in the Saint John and Hudson rivers. The catch history in the Saint John River (see above) would also support a population in that size range as the largest catch in any one year was 600 adults (DFO 2009a), and large catches were followed by years of lower catches.

St. Lawrence River DU

Harvest statistics on the fishery in the St. Lawrence River are not as comprehensive as those for the Saint John River, but annual catch records do exist from 1939 on (Figure 9; Trencia *et al.* 2002; Dadswell 2006). There was an absence of sturgeon catches in the St. Lawrence River between 1967 and 1975, but the commercial fishery then rebounded to levels higher than in the past (Figure 9). Pollution may have been responsible for the collapse in 1967 (Caron and Tremblay 1999). Catches were large in the St. Lawrence River in the 1880s (Rogers 1936), declined to < 10 t between 1939 - 1970, then increased up to 140 t in the 1970s and 1990s and have now declined to less than 40 t to 2004 (Figure 9). The median nominal age of captured sturgeon from 1984-1988 was 12 years, but dropped to 6 - 8 years from 1989-1994 as landings increased (Caron and Tremblay 1997). Without information on effort fluctuation over these time periods, however, it is impossible to use these data to estimate abundance trends.

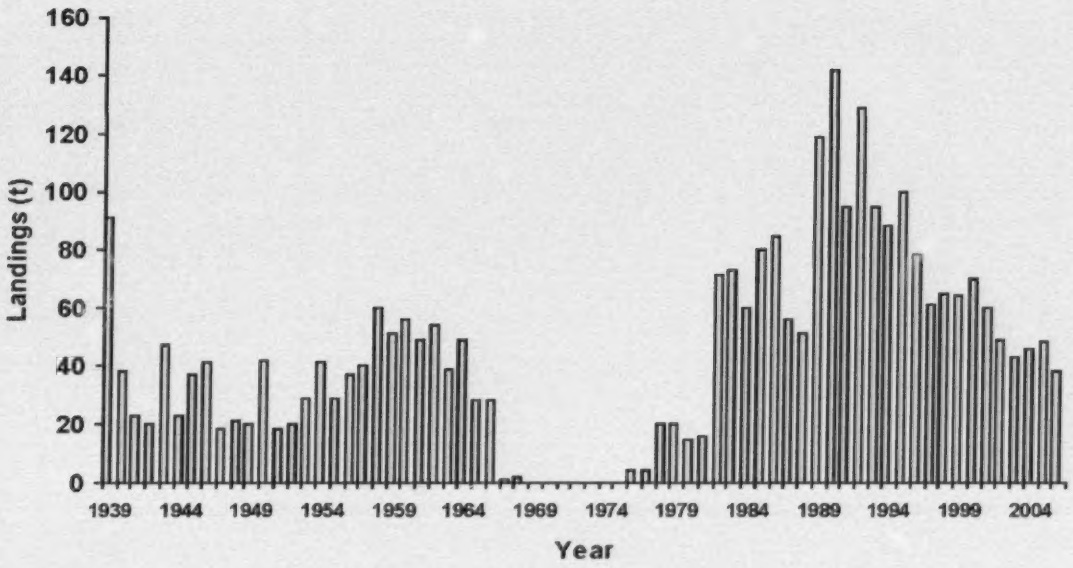


Figure 9. Commercial landings of Atlantic Sturgeon in the St. Lawrence River, 1939 - 2006 (after Dadswell 2006; DFO 2009b).

In the St. Lawrence River, where there was no size restriction until 1995, it would be difficult to estimate catch numbers. Work by Caron *et al.* (2002) captured 209 spawning fish over several weeks of gill net sampling (and some fishery landings) from 1997-2000. Dadswell (2009) used these catch and release data to suggest that the population size was between about 500 - 1,000 mature adults (calculation by Dadswell based on tag recaptures, 2009). Similarly, Verreault and Trencia (unpubl. MS, 2011) reported that fish over 150 cm fork length represented about 6% of the total catch of 3,492 fish in 2009 (i.e., 209 adults) and that total retained catch has remained stable at between 45-50 t between 2000 and 2010. Trencia *et al.* (2002) reported catch-per-unit effort for Atlantic Sturgeon in the St. Lawrence River area (CPUE = 3.82 fish/net/day in 1994 to 2.62 fish/net/day in 2000 in one reach of the river), but cautioned that even CPUE data seemed to be more dependent on water conditions and availability of prey items for sturgeon than on abundance of sturgeon. Altogether, these data suggest a relatively small population of adult sturgeon (probably < 1,000) that has remained relatively stable since the imposition of strict quotas and monitoring (see **Existing Protection** below).

Rivers in the U.S.

Atlantic Sturgeon were historically present in most eastern Atlantic river systems (Table 1, Figure 2). Of these, the population components of the Hudson and Delaware rivers are best known, and are discussed in more detail below to help put issues such as rescue effect in perspective.

The Atlantic Sturgeon population in the Hudson River is the only one that has had a portion of its population estimated. During the 1970s the juvenile population in the Hudson estuary (ages one to four years) was about 25,000 individuals (Dovel and Berggren 1983), but by 1995 was estimated to be only 4,500 individuals (Bain 1996; Peterson *et al.* 2000), a decline of 82% since 1977. The commercial fishery in the Hudson River, and along the sea coast, had effectively collapsed the spawning population by the late 1990s (Van Eeneennaam *et al.* 1996). As indicated above, research and commercial catches of spawning fish in the Hudson River varied from 200 - 350 adults annually during the 1990s (Bain 1994; Dadswell 2006) and the population in that river was estimated to be in the order of 1,000 - 2,000 adults.

On the other hand the pre-exploitation population of Atlantic Sturgeon in the Delaware River was large. Between 1887 and 1897 the commercial catch was in excess of 5,000 t annually (Ryder 1890; Murawski and Pacheco 1977) for a possible total catch during that period of 500,000 to one million adult sturgeon. The commercial fishery substantially reduced the population in the late 1800s, and again in the 1980s-1990s (Kahnle *et al.* 1998; Secor and Waldman 1999; Secor 2002, Dadswell 2006; ASSRT 2007). Today, only a remnant population remains of the 180,000 plus spawning females thought to exist in the pre-exploitation population (ASSRT 2007). The Delaware River population has never significantly recovered but the major reason may have been excessive pollution of the Delaware River since the early 1900s (Chittenden 1975).

Rescue effect

As indicated previously, Atlantic Sturgeon are highly migratory and capable of moving great distances. Young-of the-year may move downstream to the brackish waters of estuarine nursery areas, but juveniles, sub-adult and non-breeding adult Atlantic Sturgeon are generally spread out along the east coast of North America and over the continental shelf (see **Movements/Dispersal** above). There is, however, evidence that almost all riverine spawning populations are genetically distinct (see **Spatial population structure and variability** above). If that is the case, the loss of a spawning population represents a regional extirpation, at least over the medium term, and any natural and/or artificial attempt at re-colonization would represent a rescue effect from a different gene pool.

Although there has been a significant decrease in the number of mature individuals throughout the range, spawning population components appear to remain in at least 11 of the 27 known river systems (see Table 1). Thus, given the migratory behaviour of the species the possibility of natural re-colonization exists. The rebound of the St. Lawrence

River population component following the 1967 collapse (see above) may have been, at least in part, due to immigration of fish from the Gulf of St. Lawrence and/or Bay of Fundy. It is important to note, however, that where populations have been extirpated from southeastern seaboard rivers (Table 1), there has been no re-colonization, despite stocking of hatchery-raised fish (ASSRT 2007).

All extant U.S. population components exist at minimal numbers and appear to be highly stressed (Table 1; ASSRT 2007); therefore the potential for rescue from US population components is probably quite limited.

LIMITING FACTORS AND THREATS

Threats to the Atlantic Sturgeon include overexploitation, dams, habitat loss and/or degradation, and contaminants. Commercial fishing was the most significant factor that caused the historical decline of Atlantic Sturgeon populations at least in the US (Smith 1985; Dadswell 2006; DFO 2009a; NatureServe 2009).

Exploitation

Commercial fisheries

Almost all species of sturgeon worldwide have been severely impacted by either overexploitation or habitat degradation and destruction. The status of most is now management-dependent (Binkowski and Doroshov 1985). As with other sturgeons, Atlantic Sturgeon populations that have been impacted by exploitation have declined, many to very low levels (CITES World 2001; Ptolemy and Vennesland 2003; Dick *et al.* 2006; NatureServe 2009). The first period of unsustainable fisheries was during the 1880s (Ryder 1890; Smith 1985) and, for the Hudson River, the second during the 1980s (Bain 1994, 1996). Both overexploitation events led to the collapse of the targeted populations. The overall population, and probably the Canadian populations, underwent drastic declines of 50 to over 90% since commercial fishing began in the late 1800s and early 1900s, and in many areas these declines continued well into the 1900s (Dadswell 2006; ASSRT 2007; NatureServe 2009). In Delaware Bay (a major area of commercial fishing in the late 19th and early 20th centuries, stocks declined by 95% between 1891 and 1901 (Gilbert 1989). As the Atlantic Sturgeon is a slow growing, late maturing, intermittently spawning species, depleted populations, even when protected, may take many years to recover, if at all. As local commercial fishing operations have ceased or become heavily regulated across the range of the species, the decline has slowed or stopped in many populations. Nevertheless some populations (such as rivers tributary to Chesapeake Bay, particularly in Maryland; the St. Mary's River (Georgia/Florida) and possibly the St. Johns River in Florida) have become extirpated over historical periods (Dadswell 2006; ASSRT 2007; NatureServe 2009; Table 1). Where commercial fishing still exists, it typically is based on small quotas.

Prior to the fishing of the Saint John River population to commercial extirpation in the late 1800s, the population was estimated to have been in excess of 11,000 adults (see **Population Sizes and Trends**). Today it probably numbers at least 2,000 mature individuals (Dadswell 2006; ASSRT 2007; DFO 2009a) although there are no credible population size estimates available. Li *et al.* (2007) provided an estimate of 4,836 (± 69, SE) adult and sub-adult Shortnose Sturgeon (*Acipenser brevirostrum*) overwintering in a single tributary of the Saint John River, but it is unclear how well this reflects possible abundance of the Atlantic Sturgeon (the Shortnose Sturgeon is generally a smaller-bodied species). Catch records of Atlantic Sturgeon in the Saint John River suggest that historical populations have been reduced and current catches appear to be stable at low levels.

Consistent catch records for the St. Lawrence River only go back as far as 1939, but numbers were significantly impacted in the fishery of the late 1800s as they were elsewhere (Caron *et al.* 2002). The historical adult population size has never been estimated, but based on catch records had to be in excess of 3,000 adults. Current mature sturgeon may be as few as 500 adults. The apparently stable catches of sub-adult fish in the St Lawrence River commercial fishery, however, may suggest that the species can be exploited under the proper management regime (Caron and Tremblay 1999; Trencia *et al.* 2002; Verreault and Trencia unpubl. MS 2011).

Both for the Saint John River and St. Lawrence River fisheries, however, the lack of any quantitative assessments of population sizes, exploitation rate, and recruitment levels and variation makes the long-term viability of these populations under exploitation highly uncertain.

By-catch

Atlantic Sturgeon are frequently taken as incidental catch by commercial fishers using gill nets, pound nets and fyke nets. Sturgeon taken in pound nets and fyke nets are released alive, as are those which are not already moribund captured in gill nets. There is no fishery-dependent monitoring for the species in Canada; however, licensed fishers are required maintain log books detailing daily catch, effort, size and sex of sturgeon caught. The extent of compliance is, however, unclear (DFO 2009a). Such information is useful in determining presence/absence information as well as fishing mortality, including incidental catch (ASSRT 2007). By-catch mortality in Canadian fisheries is assumed to be low based on feedback from licencees.

Recreational fishery

Recreational angling for Atlantic Sturgeon is permitted in Nova Scotia, New Brunswick and Prince Edward Island under the *Maritime Provinces Fishery Regulations*. In the Maritimes, the angling season is closed in June, and there is a minimum size limit of 120 cm total length. Although basically a catch-and-release fishery, some sturgeon are retained. For example, an estimated total of 2,339 sturgeon were angled in New Brunswick in 2005 (data from a national angling survey), of which all but 41 were

reported to be released (DFO 2009A). These were probably Atlantic Sturgeon as the minimum size limit for retention is 120 cm (DFO 2009a). An assumed annual recreational angling harvest of 40 fish per year is therefore counted against the total annual losses from human activities (see **Existing Protection or Other Status Designations**). It is also possible to angle for sturgeon with a Quebec recreational fishing licence, but no information on fishing mortality is available.

Aboriginal fisheries

Currently, two Aboriginal fishing licences permit native harvests in the Maritime DU (Oromocto First Nation and the New Brunswick Peoples Council). No landings of sturgeon from these fisheries have been reported in the last five years (DFO 2009a).

Illegal harvesting

Traditionally, the source of commercial caviar has been from the larger species native to the Caspian Sea (i.e., Russian Sturgeon, *A. gueldenstaedtii*, Stellate Sturgeon, *A. stellatus*, Ship Sturgeon, *A. nudiventris*, Perian Sturgeon, *A. persicus*, and Beluga Sturgeon, *Huso huso*), particularly the Beluga, which is the largest of all sturgeons. The demand for caviar, however, is so great that these fish have been exploited to the extent that the remnant wild populations must be supplemented by aquaculture and the demand for roe is more often met by exploiting other species, perhaps including Atlantic Sturgeon (CITES World 2001). It is prohibited to retain Atlantic Sturgeon captured as by-catch in other fisheries, and illegal harvest of Atlantic Sturgeon is not considered a threat in the Maritimes DU (DFO 2009a). Atlantic Sturgeon is listed on Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). As Canada is a signatory to CITES, all exports of Atlantic Sturgeon products from Canada must be accompanied by a CITES export permit. A CITES export permit is required by importing countries, including the United States. The other eastern Canadian sturgeons that Atlantic Sturgeon could be confused with are: the Shortnose Sturgeon, which does not grow large enough to be legally taken in the fishery in the Maritimes (Dadswell 1984), and, in the St. Lawrence River, the Lake Sturgeon which are exploited in commercial and recreational fisheries in Que/bec.

Pollution

Atlantic Sturgeon appear to have a degree of tolerance for human disturbance, except in cases of extreme pollution or complete blockage of spawning rivers. For instance, Atlantic Sturgeon survived 60 years of seasonal oxygen depletion in the Delaware River and estuary and Chesapeake Bay (Brundage and Meadows 1982; Secor and Houde 1997), and remnant populations have survived in rivers, such as the Kennebec and Androscoggin rivers in Maine, since they were dammed at tide head in the 1800s (Squiers and Smith 1979). Given the migratory nature of the species, the presence of juveniles, sub-adults and adults in a particular location does not necessarily indicate a resident population.

The heavy application of the pesticide DDT in the St. Lawrence River upstream of Montreal to eradicate the mayfly hatch for Expo 67 (St. Lawrence Centre 1996), may have contributed to the demise of the Atlantic Sturgeon fishery in the estuary for the next 10 years. After landings of 20 - 60 t for 20 years previously, landings suddenly declined to virtually nothing in 1967 and remained that way until 1978 (Figure 9). Estuaries are preferred habitat for many Atlantic Sturgeon activities, providing nurseries for juveniles, and migration routes, resting sites, and feeding grounds for adults (Caron *et al.* 2002). Estuaries are also major locations of urban and industrial pollution. Pollution of the St. Lawrence River and estuary (St. Lawrence Centre 1996) has been linked to the loss or decline of numerous fish populations including Striped Bass, *Morone saxatilis* (Magnin and Beaulieu 1967), and Atlantic Sturgeon (Caron 1998). Water quality in the vicinity of suspected spawning areas near Québec City is rated as "questionable" and involves increased levels of suspended solids and phosphorus owing to increased flow and associated erosion (State of the St. Lawrence Monitoring Committee 2008). Such increased bank erosion could result in deposition of suspended material in spawning areas and smothering of incubating sturgeon eggs although no specific effects have been documented. In general areas of the middle estuary and further downstream, habitat quality is rated as "intermediate to good" (State of the St. Lawrence Monitoring Committee 2008).

Water quality in the Saint John River is very good and no impacts on Atlantic Sturgeon are known (DFO 2009a).

Habitat loss and/or degradation

Denial of access to spawning grounds has severely depleted some Atlantic Sturgeon populations. In the Saint John River, NB, construction of the Mactaquac Dam in 1969 blocked the mainstem of the river, but fortunately there are numerous alternative spawning sites around the estuary (e.g., Canaan River, Grand Lake; Rogers 1936). Also there are annual reports of large sturgeon below Mactaquac Dam and spawning probably occurs just downstream of the dam (Dadswell personal observation, 2009). Construction of a tidal power generating station on the Annapolis River in Nova Scotia has resulted in significant mortality of migrating adults (Dadswell and Rulifson 1994), but the overall effect on Atlantic Sturgeon found from time to time in the river is unknown.

The regulation of rivers by dams for hydroelectricity generation and water supply has probably affected the reproductive capacity of some populations. Atlantic Sturgeon select regions of optimal depth for spawning (Wooley and Crateau 1982), but dams alter the rise and fall of water levels. Shallow depths, lower water velocity and turbidity could cause all adults to suspend spawning activities. A major impact on habitat in the St. Lawrence River is the disposal of dredged sediments which Atlantic Sturgeon tend to avoid perhaps as a consequence of changes in distribution of their major food items (Nellis *et al.* 2007; McQuinn and Nellis 2007).

Both DUs of Atlantic Sturgeon may venture in marine waters and, in particular, travel through the Laurentian Channel area between southwest Newfoundland and Nova Scotia. This area is the site of a proposed oil and gas development ("Old Harry Project"). It is possible that this development could either in its construction or operation have some negative effects on fishes, including migrating Atlantic sturgeon (seismic testing, potential for spills). The potential for such effects is the subject of considerable investigation (CNLOPB 2011a,b).

Bayesian belief network analysis

A Bayesian belief network analysis (Nantel 2010) was used to attempt an overall analysis of trends and threats for the Atlantic Sturgeon. This analysis uses a Bayesian approach (i.e., involving some prior "knowledge" of various aspects of risk and population status) to model uncertainty of information relevant to the various COSEWIC assessment criteria. For instance, one can put in various probabilities for extents and durations of declines and probabilities for numbers of locations (e.g., 90% chance of fewer than five locations, 10% chance of more than five locations). This analysis was done for exploration purposes only and was not formally used in determining a status designation. Probabilities for the values for each of the various criteria can be obtained from E.B. Taylor (University of B.C., Dept. of Zoology, 2011). In general, inputs for criteria involving declines or population sizes were liberal (i.e., modest declines and population sizes of at least 1,000 had the highest probabilities) given the uncertainty in these parameters. Inputs for criteria involving number of locations and index of area of occupancy were more conservative (but still allowed some uncertainty) given the greater confidence in these values.

Using this approach the overall probabilities of threat status for DU1 were: criterion A (Population decline): 0.09 Endangered, 0.23 Threatened, 0.68 None (Special Concern or lower threat status); criterion B (Restricted distribution and decline): 0.25 Endangered, 0.0 Threatened, 0.75 None; criterion C (Small and declining populations): 0.17 Endangered, 0.11 Threatened, 0.72 None; criterion D (Very restricted population): 0.05 Endangered (D1), 0.13 Threatened (D1), 0.71 Threatened (D2); 0.11 None.

For DU2 (Maritimes), the overall probabilities of threat status were: criterion A (Population decline): 0.12 Endangered, 0.27 Threatened, 0.62 None (Special Concern or lower threat status); criterion B (Restricted distribution and decline): 0.0 Endangered, 0.25 Threatened, 0.75 None; criterion C (Small and declining populations): 0.11 Endangered, 0.17 Threatened, 0.72 None; criterion D (Very restricted population): 0.05 Endangered (D1), 0.36 Threatened (D1), 0.45 Threatened (D2); 0.14 None.

EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS

Canada

In Canada, the overall authority for sturgeon management rests with the Department of Fisheries and Oceans under terms of the *Fisheries Act* of 1867, and regulations thereto. By agreement with the federal government, the responsibility for the fishery in Quebec rests with the provincial government.

St. Lawrence River DU

In Quebec, the commercial fishery has been restricted to a catch of between 4,400 and 4,800 fish/year (about 60 t) since 1997 (Dumont *et al.* 2000; Trencia *et al.* 2002; Verreault and Trencia unpubl. MS 2011). A maximum size limit of 150 cm fork length has been set to protect the large, mature fish in the population (Caron *et al.* 2002; Verreault and Trencia unpubl. MS 2011). The Quebec fishing season is from May 1 to September 30 except in the tidal, freshwater zone of the St. Lawrence upstream from Québec City, where it is closed between July 1 and August 15 to prevent mortality of sturgeon in the nets. Mesh size is limited to 19 - 20 cm stretched (Caron *et al.* 2002). It is also possible to angle for sturgeon with a Québec recreational fishing permit from June 15 through October 31 with a maximum of 1 fish/day (F. Caron, Wildlife Research Branch, Quebec Department of Wildlife and Parks, Quebec, QC; personal communication 2004). In Quebec, the Atlantic Sturgeon has remained (for about 20 years) on a list of species that might be listed as a threatened or vulnerable under the *Act Respecting the Conservation and Development of Wildlife*.

Maritimes DU

The commercial fishery is regulated under a federal licence system that regulates the amount and nature of the gear (DFO 2009A). New licences are not available. There are currently five active commercial licences; four are valid for the Saint John River in New Brunswick, and one is valid for the Shubenacadie River in Nova Scotia. No licences are valid for the Gulf of St. Lawrence outside of Quebec. Licences are non-transferable and terminate with departure of the existing licensee from the fishery, a policy that has resulted in a 50% decline (from 10) in valid licences in recent years.

Any change to the present licencing policy – either to authorize transfer of existing licences or issuance of new licences – would need to be supported by a formal stock assessment (Greg Stevens, DFO, Fisheries and Aquaculture Management, Dartmouth, N.S., personal communication, 2010). The New Brunswick licensees are authorized a total of 823 m of gill net, and the Nova Scotia licensee 110 m. Additional regulations include a minimum net mesh of 33 cm, a minimum fish length of 120 cm, and a season closure in the month of June to protect spawning fish. By condition of licence all other commercial harvest fisheries are required to release Atlantic Sturgeon by-catch.

Recreational angling is permitted in Nova Scotia, New Brunswick and Prince Edward Island under the *Maritime Provinces Fishery Regulations*. In the Maritimes, the angling season is closed in June, and there is a minimum size restriction of 120 cm. The vast majority of recreational fishing for Atlantic Sturgeon occurs in the tidal waters of the Saint John River, New Brunswick which extends more than 100 km from Fredericton downstream to the Bay of Fundy. No provincial or federal recreational licence is currently required for angling sturgeon in tidal waters. There is no daily bag or possession limit but a minimum size restriction of 120 cm (Fish 2004) applies. An estimated 2,339 sturgeon were angled in New Brunswick in 2005 of which all but 41 were released. The sturgeon retained were probably Atlantic Sturgeon as the minimum size limit for retention is 120 cm (DFO 2009b).

Under CITES, before the Management Authority can issue a permit, the Scientific Authority must provide a Non-detrimental Finding (NDF) which determines if the export is detrimental to the species in the wild or not. For the Atlantic Sturgeon (Saint John River population) the NDF states that a maximum total quota of 400 fish must be respected; this includes a maximum of 350 fish for commercial harvest and the balance for recreational, aboriginal and other mortalities (removals from recreational and aboriginal fisheries should not exceed 40 fish per year). Therefore, this is the catch limit to be respected in the Saint John River population in order for export permits to be issued for Atlantic Sturgeon.

Currently, there is one active sturgeon aquaculture facility located in New Brunswick, although a second is under development. Breeding stock may be obtained by purchase of legally caught sturgeon, or through licence from the Department of Fisheries and Oceans to fish for broodstock (DFO 2009a). Conditions applied to the broodstock collection licences restrict the quantity and size of fish to be taken, the gear used, and require inspection of the facility and annual reporting. Since 2000, 52 Atlantic Sturgeon have been removed from the wild for artificial breeding, and licences to remove gametes from 10 pairs of adults were issued between 2003 - 2008 (the fish were returned to the wild after gamete extraction).

United States

The status of Atlantic Sturgeon has been under continuous review in many jurisdictions throughout its range for the last twenty years. In 1998, Atlantic populations in the United States were considered for listing according to the *Endangered Species Act*; however, listing was considered unwarranted at the time, but the species was retained on the Candidate species list (NMFS l998b; NatureServe 2009). In January 2010, the U.S. National Oceanographic and Atmospheric Administration (NOAA) announced a proposal for listing of Atlantic Sturgeon as Threatened or Endangered under the *U.S. Endangered Species Act* (NOAA 2010).

In the U.S., Atlantic Sturgeon are managed under the Atlantic States Marine Fisheries Commission Interstate Fishery Management Plan in accordance with state regulations, and since 1998 commercial fishing has been prohibited along the entire United States Atlantic coast by those states participating in the plan (Friedland 2000; Dadswell 2006). The Gulf Atlantic Sturgeon (*A o. desotoi*) was listed as threatened by the United States federal government in 1991 and the fishery closed (NMFS 1998b).

Before 1998, some U.S. state jurisdictions considered Atlantic Sturgeon threatened or endangered but in others it was regulated as a commercial fishery. In all states with a commercial fishery, harvesting was regulated by gear restrictions, size restrictions or a total catch limit, and in some states, a tagging system (Young 1994; NMFS 1998b).

International

As a wide-ranging anadromous species, Atlantic Sturgeon are subject to numerous U.S. and Canadian federal, state/provincial, and inter-jurisdictional laws, regulations and management agency activities. Internationally, they are listed under Appendix II to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) as a species that may become threatened if trade is not regulated, and trade is regulated under a permit system. It is listed on the International Union for the Conservation of Nature (IUCN) Red List as a species of lesser risk.

ACKNOWLEDGEMENTS

The World Wildlife Fund provided a grant to prepare this status report. Fisheries biologists and managers in Quebec (F. Caron and Guy Verreault), New York State (M. Bain), North Carolina (R. Rulifson), South Carolina (T. Smith), and Florida (K. Sulak) provided helpful discussions and supplied published and unpublished data. M. Etter of the Department of Fisheries and Oceans provided sturgeon landing statistics for the Maritimes and Rod Bradford (DFO, Moncton) provided helpful information. M. Walters assisted with literature searches and collation of data.

INFORMATION SOURCES

Anonymous. 2002. A proposal to prepare a concept for a multi-faceted sturgeon production and research facility. AMEC Earth and Environmental Limited, Fredericton, NB.

Appy, R. G., and M.J. Dadswell. 1978. Parasites of *Acipenser brevirostrum* LeSueur and *Acipenser oxyrhynchus* Mitchill (Osteichthyes:Acipenseridae) in the Saint John River estuary, NB., with a description of *Caballeronema pseudoargumentosus* sp.n. (Nematoda: Spirurida). Canadian Journal of Zoology 56:1382-1391.

Armitage, I.A., and M.K. Gingras. 2003. Potential for the restoration of the Roanoke River population of Atlantic sturgeons. Journal of Applied Ichthyology 18: 475-480.

Armstrong, J.L., and J.E. Hightower. 2002. Potential for restoration of the Roanoke River population of Atlantic sturgeon. Journal of Applied Ichthyology 18: 475-480.

ASSRT (Atlantic Sturgeon Status Review Team. 2007. Status review of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*). Report to the National Marine Fisheries Service, Northwest Regional Office, Gloucester, MA. pp 187.

Bain, M. 1994. Changes in the composition of Hudson River sturgeon. Sturgeon Notes 3: 7.

Bain, M. 1997. Atlantic and shortnose sturgeons in the Hudson River: common and divergent life history attributes. Environmental Biology of Fishes 48: 347-358.

Bain, M. 1996. A population estimate for age 1 Atlantic sturgeon in the Hudson River. Sturgeon Notes 4: 13.

Bigelow, H.B., and W. C. Schroeder. 1953. Fishes of the Gulf of Maine. Fish Bull. 53.

Binkowski, F.P., and S. I. Dorosov. 1985. (Eds.). North American sturgeons: biology and aquaculture potential. Junk, Netherlands.

Boreman, J. 1997. Sensitivity of North American sturgeons and paddlefish to fishing mortality. Environmental Biology of Fishes 48: 399-405.

Brennan, J.S., and G.M. Caillet. 1989. Comparative age-determination techniques for white sturgeon in California. Transactions of the American Fisheries Society I I 8: 296-310.

Brundage, H.M.III, and R.E. Meadows. 1982. The Atlantic sturgeon, *Acipenser oxyrynchus*, in the Delaware River estuary. Fisheries Bulletin 81:337-343.

Burkett, C, and C, Kynard. 1993. Sturgeons of the Taunton River and Mt. Hope Bay. Distribution, habitat and movements. Final Report to Project AFC-24-1, Massachusetts Division of Marine Fisheries, Boston, Massachusetts.

Burkhead, N.M., and R.E. Jenkins. 1991. Fishes. Pages 321-409 in Virginia's species. Proceedings of a symposium, Coordinator K. Terwilliger. McDonald and Woodward, Blacksburg.

Bushroe, T.M., A. Musick, and D.S. Ha (Draft). 2005. Essential spawning and nursery habitat of Atlantic sturgeon (*Acipenser oxyrinchus*) in Virginia. Virginia Institute of Marine Science, Gloucester Point, Virginia.

Canadian Endangered Species Council. 2006. The general status of species in Canada. Ottawa: Minister of Public Works and Government Services.

Caron, F. 1998. Discovery of an adult Atlantic sturgeon (*Acipenser oxyrinchus*) concentration site in the St. Lawrence River, Quebec. Sturgeon Notes 5: 18.

Caron, F., and S. Tremblay. 1997. Structure and Management of an Exploited Population of Atlantic Sturgeon (*Acipenser oxyrinchus*) in the St. Lawrence Estuary, Quebec, Canada. Ministere de l'Environment et de la Faune. 11 pp.

Caron, F., and S. Tremblay. 1999. Structure and management of an exploited population of Atlantic sturgeon (*Acipenser oxyrinchus*) in the St. Lawrence estuary, Quebec, Canada. Journal Applied Ichthyology, 15: 153- 1 56.

Caron, F., D. Hatin, and R Fortin. 2002. Biological characteristics of adult Atlantic sturgeon (*Acipenser oxyrinchus*) in the St Lawrence River estuary and the effectiveness of management rules. Journal Applied Ichthyology, 18: 580-585.

Chan, M.D., D. Dibble and K.J. Kilgore. 1997. A laboratory examination of water velocity and substrate preference by Age-0 Gulf sturgeons. Transactions American Fisheries Society, 126: 330-333.

CITES World. 2001. A new focus for CITES World - Strugeons, significant trade and the "Paris Agreement". CITES world 8 (December 2001): I-16.

Chittenden, M.E. Jr. 1975. Dynamics of American shad, *Alosa sapidissima*, runs in the Delaware River. Fisheries Bulletin, 7 4: 343-352.

Chittenden, M. E. Jr. 1976. Present and historical spawning grounds and nurseries of American shad, *Alosa sapidissima*, in the Delaware River. Fisheries Bulletin,T4: 343-352.

CNLOPB (Canada-Newfoundland and Labrador Offshore Petroleum Board). 2011a. Offshore western Newfoundland 2008-2016 seismic survey program. http://www.cnlopb.nl.ca/environment/nwenergy.shtml. accessed May 11, 2011.

CNLOPB (Canada-Newfoundland and Labrador Offshore Petroleum Board). 2011b. Corridor Resources Inc. Drilling of an Exploration Well on the Old Harry Prospect - EL 1105. http://www.cnlopb.nl.ca/environment/corridorresinc.shtml. Accessed May 11, 2011.

Colligan, M., M. Collins, A. Hecht, M. Hendrix, A. Kahnle, W. Laney, R. St. Pierre, R. Santos, and T. Squiers. 1998. Status review of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*). Atlantic Sturgeon Status Review Team, 124 p.

Collins, M,R., and T.I.J. Smith. 1997. Distribution of shortnose and Atlantic sturgeons in South Carolina. North American Journal of Fisheries Management 17: 995-1000.

Collins, M.R., T.I.J. Smith, W.C. Post, O. Pashuk. 2000. Habitat utilization and biological characteristics of adult Atlantic sturgeon in two South Carolina rivers. Transactions American Fisheries Society, 129: 982-988.

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2009. COSEWIC Operations and Procedures Manual, July 2009. Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Ottawa. Xi + 57 pp + Appendices A-F.

Cox, P. 1893. Observations on the distribution and habits of some New Brunswick fishes. Bulletin of the Natural History Society of New Brunswick 11: 33-42.

Dadswell, M. J. 1979. Biology and population characteristics of the shortnose sturgeon, *Acipenser brevirostrum* LeSueur, 1818 (Ostreichthyes: Acipenseridae), in the Saint John River estuary, New Brunswick, Canada. Canadian Journal Zoology, 57: 2186-2210.

Dadswell, M. J. 1984. The status of shortnose sturgeon, *Acipenser brevirostrum*, in Canada. Canadian Field-Naturalist, 98:7 5-79.

Dadswell, M.J. 2006. A Review of the Status of Atlantic Sturgeon in Canada with Comparisons to Populations in the United States and Europe. Fisheries 31(5): 218-229.

Dadswell, M.J., R. Bradford, A.H. Leim, G.D. Melvin, R.G. Appy and D.J. Scarratt. 1984. A review of fish and fisheries research in the Bay of Fundy between 1976 and 1983. In. D.C. Gorden, and M.J. Dadswell (Eds.). Update on marine environmental consequences of tidal power development in the upper reaches of the Bay of Fundy. Canadian Technical Report Fisheries Aquatic Sciences, 1 256: 263-294.

Dadswell, M.J. and R.A. Rulifson. 1994. Macrotidal estuaries: a region of collision between migratory marine animals and tidal power development. Biology Journal Linnaean Society 51 : 93-I 13.

Dick, T.A., R.R. Campbell, N.E. Mandrak, B. Cudmore, J.D. Reist, J. Rice, P. Bentzen, and P. Dumont. 2006. COSWIC Status Report on the Lake Sturgeon, Acipenser fulvescens, in Canada. Committee on the Status of Endangered Wildlife in Canada (COSEWIC) CWS, Ottawa. v + 120 p.

DFO (Department of Fisheries and Oceans). 2009a. Evaluation of Atlantic Sturgeon (*Acipenser oxyrinchus*) in the Maritimes Region with respect to Making a CITES Non-detriment Finding. DFO Canadian Science Advisory Section Scientific Advise Report 2009/09.

DFO (Department of Fisheries and Oceans). 2009b. Commerical fisheries landings: Freshwater. Available at: www.dfo-mpo.g.c/ca/stats/commerical/land-debarq/freshwater=eaudouc 9/29/2009.

Dovel, W.L., and T.J. Berggren. 1983. Atlantic sturgeon of the Hudson River estuary, New York. N. Y. Fish. And Game Journal, 30: 140-172.

Dumont, P., R. Fortin, G. Desjardins and M. Bernard. 1987. Biology and exploitations of lake sturgeon (*Acipenser fulvescens*) on the Quebec waters of the Saint-Laurent River. Pp. 57-76 in Olver, C.H. (ed.). Proceedings of a workshop on the lake sturgeon (*Acipenser fulvescens*). Ontario Fisheries Technical Report Series No. 23.

Dumont, P., Yves Mailhot, Réjean Dumas, et Pierre Bilodeau. 2000. Plan de gestion de l'esturgeon jaune du fleuve Saint-Laurent. Société de la faune et des parcs du Québec. FAPAQ. Directions de l'aménagement de la faune du Centre-du- Québec, de Lanaudière, de la Montérégie et de Montreal. 2l p.

Fish. 2004. Angling regulations and licence information. New Brunswick Department of Natural Resources, Fish and Wildlife Branch, Fredericton, NB.

Fortin, R., J. Mongeau, G. Desjardins and P. Dumont. 1993. Movements and biological statistics of lake sturgeon (*Acipenser fulvescens*) populations from the St. Lawrence and Ottawa River system, Quebec. Canadian Journal of Zoology 71: 638-650.

Foster, A.M. and J.P. Clugston. 1997. Seasonal migration of the Gulf sturgeon in the Suwanee River, Florida. Transactions American Fisheries Society, 126:302-308.

Fox, D.A., J.E. Hightower, and F.M. Parauka. 2000. Gulf sturgeon spawning migration and habitat in the Choctawhatchee River system, Alabama-Florida. Transactions American Fisheries Society , 129:81 I -826.

Friedland, Kevin. 2000. Status of fisheries resources off Northeastern United States - Atlantic and shortnose sturgeons. Web site accessed April 2004: http ://www. nefsc.noaa. gov/sos/spsyn/aflsturgeon.

Galbreath, J.L. 1985. Status, life history and management of the Columbia River white sturgeon, *Acipenser transmontanus*, *In* Binkowski, F. P. And S. I. Doroshov (Eds.) North American sturgeons: biology and aquaculture potential pp 119-125. Junk, Netherlands.

Gagnon, M., Y. Menard, and J.-F. La Rue. 1993. Caractérisation et evaluation des habitats du poisson dans la zone de transitionsaline du Saint-Laurent. Rapp. Tech. Can. Sci. Halieut. 1920: viii + 104 pp.

Gilbert, C.R. 1989. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Atlantic Bight - Atlantic and shortnose sturgeons. U.S. fish and Wildlife Sevice Biological Report 82(11.122). 28 p.

Grunwald, C., L, Maceda, J. Waldman, J. Stabile, and I. Wirgin. 2008. Conservation of Atlantic sturgeon, *Acipenser oxyrinchus oxyrinchus*: delineation of stock structure and distinct population segments. Conservation Genetics 9: 1111-1124.

Grutchy, C.G., and B. Parker. 1978. *Acipenser oxyrhynchus* Mitchell, Atlantic sturgeon. Page 41 *in*; Atlas of North American freshwater fishes. *Edited by* D.S. Lee, C.R. Gilber, C.H. Hocutt, R.E. Jenkins, D.E. McAllister, and J.R. Stauffer, Jr. 1980. North Carolina State Museum of Natural History, North Carolina Biological Survery #1980-12.

Guibard, F., J. Munro, P. Dumont, D. Hatin and R. Fortin. 2007. Feeding ecology and Atlantic sturgeon and lake sturgeon co-occurring in the St. Lawrence Estuary transition zone. Am. Fish. Soc. Symp. 56: 85-104.

Hardy, R., and M.K. Litvak. 2004. The effect of temperature on the early development of larval shortnose and Atlantic sturgeon. Environmental Biology of Fishes. 70:145-154.

Hatin, Daniel, Frangois Caron and Réjean Fortin. 1998. Recherche de géniteurs, de frayères et de juveniles d'esturgeon noir (*Acipesnser oxyrinchus*) dans l'estuaire fluvial du Saint-Laurent. Québec Ministère de l'Environnement et de la Faune Direction de la Faune et des Habitats, Québec, QC. 40 p.

Hatin, D., R. Fortin, and F. Caron. 2002. Movements and aggregation areas of adult Atlantic sturgeon (*Acipenser oxyrinchus*) in the St. Lawrence River estuary, Quebec, Canada. Journal Applied Ichthyology, 18: 586-594.

Hatin, D., J. Munro, F. Caron, R.D. Simons. 2007. Movements, home range, and habitat use and selection of early juvenile Atlantic sturgeon in the St. Lawrence Estuarine transition zone. Am. Fish. Soc. Sym. 56: 129-156.

Heise, R.J., W.T. Slack, S.T. Ross, and M.A. Dugo. 2004. Spawning and associated movement patterns of Gulf sturgeon in the Pasagoula River drainage, Mississippi. Transactions of the American Fisheries Society 133: 221-230.

Hoff J.G. 1980. Review of the present status of the stocks of the Atlantic sturgeon, *Acipenser oxyhrhynchus*. National Marine Fisheries Service, Northeastern Region, Glouchester MA. 136 p.

Holland, B.F. Jr. and G.F. Yelverton. 1973. Distribution and biological studies of anadromous fishes offshore North Carolina. N. C. Department Natural Resources Special Science Report :.24.

Huff, J. A. 1975. Life history of Gulf of Mexico sturgeon, *Acipenser oxyrynchus desotoi*, in Suwanee River, Florida. Florida Marine Research Publication 16.

Jarvis, Peter L.; J.S. Ballantyne, and W.E. Hogans. 2001. The Influence of Salinity on the Growth of Juvenile Shortnose Sturgeon. North American Journal of Aquaculture 63: 272–276.

Johnson, J.H., D.S. Dropkin, B.E. Warkentine, J.W. Rachlin, and W. D. Andrews. 1997. Food habits of Atlantic sturgeon off the central New Jersey coast. Transactions American Fisheries Society, 126:166-170.

Johnson, J.H., J.E. McKenna,, Jr., D.S. Dropkin, and W.E. Andrews. 2007. A novel approach to fitting the Von Bertalanffy relationship to a mixed stock of Atlantic Sturgeon harvested off the New Jersey coast. Northeastern Naturalist 12(2): 195-202.

Kahnle, A.W., K.A. Hattala, K.A. McKown, C.A. Shrey, M.R. Collins, T.S. Squiers Jr., and T. Savoy. 1998. Stock status of Atlantic Sturgeon of Atlantic estuaries. Report for the Atlantic States Marine Fisheries Commission: Draft III, Washington, DC.

Kahnle, A.W., R.W. Laney, and B.J. Spear. 2005. Proceedings of the workshop on the status and management of Atlantic Sturgeon Raleigh, N.C., 3-4 November 2003. Special Report NC. 84 of the Atlantic States Marine Fisheries Commission, Washington, DC.

Kieffer, M.C. and B. Kynard. 1993. Annual movements of shortnose and Atlantic sturgeons in the lower Merrimack River, Massachusetts. Transactions American Fisheries Society 122: 1088-1 103.

King, T.L. B.A. Lubinski, and A.P. Spidle. 2001. Microsatellite DNA variation in Atlantic sturgeon, *Acipenser oxyrinchus*, and cross-species amplification in the Acipenseridae. Conservation Genetics 2: 103-1 19.

Krayushkina, L.S. 1998. Characteristics of osmotic and diadromous sturgeons *Acipenser brevirostrum* and *A. oxyrhynchus* (Acipenseridae). Journal Ichthyology 38: 660-668

Lazzari, M.A., J.C. O'Herron II, and R.W. Hastings. 1986. Occurrence of juvenile Atlantic sturgeon, *Acipenser oxyrynchus*, in the upper tidal Delaware River. Estuaries 9: 356-361.

Li, X., M.K. Litvak, and J.E. Hughes Clarke. 2007. Overwintering habitat use of shortnose sturgeon (*Acipenser brevirostrum*): defining critical habitat using a novel underwater video survey and modeling approach. Can. J. Fish. Aquat. Sci. 64: 1248-1257.

Lleim, A.H., and W.B. Scott. 1966. Fishes of the Atlantic coast of Canada. Fisheries Research Board of canada, Bulletin No. l I7. 485 pp.

Ludwig, A., L. Debus, D. Lieckfeldt, I. Wirgin, N. Benecke, I. Jenneckens, P. Williot, J.R. Waldmen, and C. Pitra. 2002. When the American sea sturgeon swam east. Nature 419: 447-448.

Magnin, E. 1962. Recherches sur la systematique et la biologie des Acipenserides, *Acipenser sturio* L., *Acipenser oxyrhynchus* Mitchill et *Acipenser fulviscens* Raf. Annales statione centrale d'Hydrobiologie Appliés. 9.

Magnin, E. 1964. Croissance en longueur de trios sturgeons d'Amerique du Nord: *Acipenser onyrhynchus* Mitcvhell, *Acipenser fulvescens* Raffinesque, et *Acipenser brevirostris* Le Sueur. Verh. Interat. Verein. Limnol. 968-974.

Magnin, E., and G. Beaulieu. 1967. Le bar, *Roccus saxatilus* (Walbaum), du fleuve Saint-Laurent. Naturaliste Canadienne. 91: 5-20.

Maryland. 2003. Fact sheet - Atlantic sturgeon, *Acipenser oxyrhinchus*. Maryland State Fisheries Education web Site accessed 24 march 2004; httP://www.dnr.state.md.us/fishereis/education/sturgeon/sturgeon.html

McKenzie, R. A. 1959. Marine and freshwater fishes of the Miramichi River and estuary, New Brunswick. Journal Fisheries Research Board Canada 16: 807-833.

McQuinn, I.H., and P. Nellis. 2007. An acoustic-trawl survey of middle St. Lawrence Estuary demersal fishes to investigate the effects of dredged sediment disposal on Atlantic sturgeon and lake sturgeon distribution. Am. Fish. Soc. Sym. 56: 257-271.

Mohler, J., and J. Fletcher. 1998. Report of 1997 capture efforts for broodstock Atlantic sturgeon on the Hudson River. Page 5 *in:* Sturgeon Notes, Issue No. 5. *Edited by* K. Arend. Cornell University and the Hudson River Foundation.

Moser, M.L., and S.W. Ross. 1995. Habitat use and movements of shortnose and Atlantic sturgeons in the lower Cape Fear River, North Carolina. Transactions American Fisheries Society 124: 225-234.

Mosindy, T. and J. Rusak. 1991. An assessment of the lake sturgeon populations in Lake of the Woods and the Rainy River 1987-90. Lake of the Woods Fisheries Assessment Unit Report. Ontario Ministry of Natural Resources, Kenora, ON. 59 pp.

Murawski, S.A. and A.L. Pacheco . 1977. Biological and fisheries data on Atlantic sturgeon, *Acipenser oxyrhynchus* (Mitchill). National Marine Fisheries Service Technical Report 10.

Nantel, P. 2010. A Bayesian belief network for assessing species status under uncertainty. Available from Patrick Nantel, Parks Canada, Ottawa, Ontario.

Nellis, P., S. Senneville, J. Munro, G. Drapeau, D. Hatin, G. Desrosiers, and F.J. Saucier. 2007. Tracking the dumping and bed load transport of dredged sediment in the St. Lawrence estuarine transition zone and assessing their impacts on macrobenthos in Atlantic sturgeon habitat. Am. Fish. Soc. Symp. 56: 215-234.

NMFS (National Marine Fisheries Service). 1998a. One-year findings of a petition to list the Atlantic sturgeon, *Acipenser oxyrinchus*, in the United States as Threatened. Federal Register 63(182): 50187-50 r99.

NMFS (National Marine Fisheries Service). 1998b. Status review of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*). NMFS Protected Resources Division Northeast Region, Gloucester, MA. 126 pp.

NatureServe. 2009. NatureServe Explorer: An online encyclopaedia of life (web application). Version 7.1. NatureServe, Arlington, Virginia. Available at: http://www.naturserve.org/explorer. (Accessed: September 12, 2009).

Nelson, J.S., E.J. Crossman, H. Espinosa-Perez, L.T. Findley, C.R. Gilbert, R.N. Lea and J.D. Williams. 2004. Common and Scientific Names of Fishes from the United States, Canada, and Mexico. 6th Edition. Am. Fish. Soc. Sp. Pub. 29. Bethesda MD. 386 pp.

NOAA (National Oceanographic and Atmospheric Administration). 2010. NOAA Considers Listing Atlantic Sturgeon as Endangered or Threatened. NOAA Press Release 10 January 2010, Washington, DC.

Ong, T-L., J. Stabile, I. Wirgin, and J.R. Walsman. 1996. Genetic divergence between *Acipenser oxyrinchus* and *A. o. desotoi* as assessed by mitochondrial DNA sequencing analysis. Copeia 1996.

Page, I.M., and B.M. Burr. 1991. A field guide to freshwater fishes: North America north of Mexico. Houghman Companiy, Boston. 432p.

Paragamian, V.L., and R.C.P. Beamesderfer. 2003. Growth estimates from tagged white sturgeon suggest that ages from fin rays under estimate true age in the Kootenai River, USA and Canada. Transactions of the American Fisheries Society 132: 895-903.

Peterson, D.L., M.B. Bain and N. Haley. 2000. Evidence of declining recruitment of Atlantic sturgeon in the Hudson River. North American Journal Fisheries Management 20: 23 I -238.

Probst, T. and E.L. Cooper. 1954. Age, growth, and production of the lake sturgeon, *Acipenser fulvescens*, in the Lake Winnebago region, Wisconsin. Transactions of the American Fisheries Society 84: 207-227.

Ptolemy, Juanita, and Ross Vennesland. 2003. Update COSEWIC status report on the white sturgeon, Acipenser transmontanus, in Canada. Committee on the Status of Endangered wildlife in Canada (COSEWIC). Ottawa. 26 p.

Reiman, B.E., and F.W. Allendorf. 2001. Effective population size and genetic conservation criteria for bull trout. North American Journal of Fisheries Management 21(4): 756-764

Rogers, H.M. 1936. The estuary of the Saint John River. Its physiography, ecology, and Fisheries. M. A. Thesis. University of Toronto.

[illegible]ers, S.G., and W. Weber. 1995. Status and restoration of Atlantic and shortnose sturgeon in Georgia. Final Report to National Marine Fisheries Service, Southeast Region, St. Petersburg, Florida.

Ryder, J. A. 1890. The sturgeon and sturgeon fisheries of the eastern coast of the United States, with an account of experiments bearing upon sturgeon culture. U.S. Fisheries Commission Bulletin. (1888)8: 231-239.

Savoy, T. 1996. Anadromous fish studies in Connecticut waters. Completion Report AFC-22-3 Connecticut Department of Environmental Protection, Hartford, Connecticut.

Savoy, T. and D. Palileo. 2003. Movements and important habitats of subadult Atlantic sturgeon in Connecticut waters. Transactions American Fisheries Society 132: 1-8.

Rogers, S.G., P.H. Flournoy, and W. Weber. 1994. Status and restoration of Atlantic sturgeon in Georgia. Final report to NMFS for grant No. NA16FA0098-01-02 and -03.

Schuller, P., and D.L. Peterson. 2006. Popualtion status and spawning movements of Atlantic sturgeon in the Altamaha River , Georgia. Presnetation to the 14th American Fisheries Society Sothern Diviion Meeting, San Antonio, February 812, 2006.

Scott, W.B and E.J. Crossman. 1998. Freshwater fishes of Canada. Revised Edition. Galt House Publishing, Oakville ON. 966 pp.

Scott, W. B. and M. C. Scott. 1988. Atlantic fishes of Canada. Canadian Bulletin Fisheries Aquatic Sciences 219.

Secor, D.H. 2002. Atlantic sturgeon fisheries and stock abundance during the late nineteenth century. American Fisheries Society Symposium 28: 89-98.

Secor, D.H., and E.D. Houde. 1997. Effects of Hypoxia and temperature on growth, survival and respiration of juvenile Atlantic sturgeon. Maryland Department Natural Resources (UMCEES)CBL 97-025 .

Secor, D.H., and J.R. Waldman. 1999. Historical abundance of Delaware Bay Atlantic Sturgeon, and potential rate of recovery. American Fisheries Society Symposium 23: 203-216.

Secor, D.H. and E.J. Niklitschek. 2001. Hypoxia and sturgeons. Technical Report Series No. TS-314-01-CBL.

Secor, D.H., E.J. Niklitschck, J.T. Stevenson, T.E. Gunderson, S.P. Minkkinson, B. Richardson, B. Florence, M. Mangold, J. Skjeveland, and A. Henderson-Arspalo. 2000. Dispersal and gworth of yearling Atlantic sturgeon, *Acipenser oxyrinchus*, released into Chesapeake Bay. Fisheries Bulletin 98: 800-810.

Sibun, J. 2007. Price of Beluga caviar up nearly 50%. Telegraph, London, 01 Dec 2007. Pulished online at www.telgraph.co.uk/finance/newsby accessed 12 Sep 09.

Smith, H. M. 1907. The fishes of North Carolina. North Carolina Geological Economic Survey 11.

Smith, T.I.J. 1985. The fishery, biology, and management of Atlantic sturgeon, *Acipenser oxyrhynchus* (Mitchill) in North America. Environmental Biology Fishes 14:61-72.

Smith, T.I.J., D.E. Marchette, and G.F. Ulrich. 1984. The Atlantic sturgeon fishery in South Carolina. North American Journal Fisheries Management 4: 164-176.

Snyder, D.E. 1988. Description and identification of shortnose and Atlantic sturgeon larvae. American Fisheries Society Symposium 5:7-30.

Squiers, T.S. 2005. State of Maine 2005. Atlantic sturgeon compliance report to the Atlantic States Marine Fisheries Commission. Report submitted to Atlantic States Marine Fisheries Commission, September 20, 2005, Washington, DC.

Squiers, T.S. and M. Smith. 1978. Distribution and abundance of shortnose and Atlantic sturgeon in the Kennebec River estuary. Progress Report Department. Maritime Resources, Maine AFC-19-1.

St. Lawrence Centre. 1996. State of the environment report on the St. Lawrence River. Vol. 1: The St. Lawrence Ecosystem. Environment Canada-Quebec Region.

State of the St. Lawrence Monitoring Committee. 2008. Overview of the State of the St. Lawrence River 2008. St. Lawrence Plan. Environment Canada, Ministère du Développement durable, de l'Environnement et des Parcs du Québec, Ministère des Ressources naturelles et de la Faune du Québec, Fisheries and Oceans Canada, and Stratégies Saint-Laurent. 28 pp. http://www.mddep.gouv.qc.ca/eau/flrivlac/fleuve_en.htm#limites

Stein, A.B., K.D. Friedland, and M. Sutherland. 2004. Atlantic sturgeon marine distribution and habitat use along the northeastern coast of the United States. Transaction of the American Fisheries Society 133: 527-537.

Sulak, K. J. and J.P. Clugston. 1998. Early life history stages of Gulf sturgeon in the Suwannee River, Florida. Transactions American Fisheries Society 127:758-771.

Trencia, G.,G. Verrault, S. George and P. Pettigrew. 2002. Atlantic sturgeon (*Acipenser oxyrhinchus oxyrhinchus*) fishery management in Quebec, Canada, between 1994-2000. Journal Applied Ichthyology 18: 455-462.

Tracy, H.C. 1905. A list of fishes of Rhode Island. *In* 36th Annual Committee on Island Fisheries, Providence, Rhode Island.

Van Eenennaam, J.P., S.I. Doroshov, G.P. Moberg, J.G. Watson, D.S. Moore and J. Linares. 1996. Reproductive conditions of the Atlantic sturgeon (*Acipenser oxyrhinchus)* in the Hudson River. Estuaries 19: 769-777.

Verreault, G., and G. Trencia. 2011. Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) fishery management in the St. Lawrence Estuary, Québec, Canada. Unpubl. MS available from G. Verreault Ministere des Ressources Naturelle et de la Faune, 186 rue Fraser, Rivière du Loup, QC

Vladykov, V.D. and J.R. Greeley. 1963. Order Acipenseroidei. In Fishes of Western North Atlantic. Sears Foundation Marine Research, Yale University 1(3): 630 pp..

Waldman, J.R., and I.I. Wirgin. 1998. Status and restoration options for Atlantic sturgeon in North America. Biology 12:631-638.

Waldman, J.R., J.T. Hart, and I.I. Wirgin. 1996. Stock composition of the New York Bight Atlantic sturgeon fishery based on analysis of mitochondrial DNA. Transactions of the American Fisheries Society 125. 364-371.

Waldman, J.R., C. Grunwald, J. Stabile, and I. Wirgin. 2002. Impacts of life history and biogeography on genetic stock structure in Atlantic sturgeon, *Acipenser oxyrinchus oxyrinchus*, Gulf Sturgeon, *Acipenser oxyrinchus desotoi*, and shortnose sturgeon, *Acipenser brevirostrum*. Journal of Applied Ichthyology 18: 509-518.

Waples, R.S. 1991. Pacific salmon, *Oncorhynchus* spp., and the delineation of "species" under the Endangered Species Act. Marine Fish Review 53:11-22.

Wehrell, S. 2005. A survey of the groundfish caught by summer trawl fishery in Minas Basin and Scots Bay. Honours Thesis. Department of Biology, Acadia University, Wolfville, Nova Scotia.

Wharon, J. 1957. The bounty of the Chesapeake Bay fishing in colonial Virginia. University Press, Charlottesville, Virginia.

Whitworth, M.S. 1996. Freshwater fishes of Connecticut. State Geological and Natural H istroy Survey of Connecticut, Connecticut Department Bulletin 114, Hartford, Connecticut.

Wirgin, I, J.R. Waldman, J. Rosko, R. Gross, M.R. Collins, S.G. Rogers, and J Stabile. 2000. Genetic structure of Atlantic sturgeon populations based on mitochondrial DNA control region sequences. Transactions of the American Fisheries Society 129: 476-486.

Wooley, C.M. and E.J. Crateau. 1985. Movement, microhabitat, exploitation, and management of Gulf sturgeon, Apalachicola River, Florida. North American Journal Fisheries Management 5: 590-605.

Young, B. 1994. New York State 1993 Atlantic sturgeon fishery. SturgeonNotes 2:5.

BIOGRAPHICAL SUMMARY OF REPORT WRITER

R. Campbell is a former co-chair of the COSEWIC Freshwater Fishes SSC, and formerly CITES Management Authority for Canada, and Senior Policy Program Advisor Northern and Inland Fisheries, Department of Fisheries and Oceans. Bob has authored and co-authored several COSEWIC reports and currently works as a free-lance consultant on environmental and fishery-related issues mainly dealing with species at risk.

COLLECTIONS EXAMINED

None

AUTHORITIES CONSULTED AND PERSONAL COMMUNICATIONS

Bain, M. National Marine Fisheries Service, Milford, Connecticut.

Bradford, R. Department of Fisheries and Oceans, Diadromous Fish Division, Dartmouth, Nova Scotia.

Caron, F. Wildlife Research Branch, Quebec Department of Wildlife and Parks Quebec, Quebec.

Douglas, S. Department of Fisheries and Oceans, Diadromous Fish Section, Gulf Region, Moncton, New Brunswick.

Elderkin, M. Wildlife Division, Nova Scotia Department of Natural Resources, Kentville, Nova Scotia.

M. Etter. Department of Fisheries and Oceans, Fish Division, Bedford Institute of Oceanography, Dartmouth, Nova Scotia

Jessop, M.B. Diadromous Fish Division, Bedford Institute of Oceanography, Dartmouth, Nova Scotia.

Rulifson, R. Department of Biology, East Carolina State University, Breenville, North Carolina,

Smith, T. South Carolina Wildlife and Marine Resources Department, Marine Resources Research Institute, Charleston, South Carolina.

Sulak, K. Research Fishery Scientist, United States Geological Survey, Gainsville, Florida.

Guy Verreault, G. Direction de l'Expertise du Bas-Saint-Laurent Ministère des Ressources Naturelles et de la Faune, Rivière-du-Loup, Québec.